Established by BENJAMIN SILLIMAN in 1818.

PUBLIC LIBRARY
OF THE
CITY OF DETROIT

THE AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS GEORGE L. GOODALE, JOHN TROWBRIDGE, W. G. FARLOW AND WM. M. DAVIS, OF CAMBRIDGE,

PROFESSORS ADDISON E. VERRILL, HORACE L. WELLS, L. V. PIRSSON AND H. E. GREGORY, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA,
PROFESSOR HENRY S. WILLIAMS, OF ITHACA,
PROFESSOR JOSEPH S. AMES, OF BALTIMORE,
MR. J. S. DILLER, OF WASHINGTON.

FOURTH SERIES

VOL. XX—[WHOLE NUMBER, CLXX.]

No. 118.—OCTOBER, 1905.

WITH PLATE IX.

NEW HAVEN, CONNECTICUT.

1905

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 123 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

RARE MINERALS

IN TON LOTS

Correspondence solicited with miners or consumers of the ores of

Molybdenum
Tantalum
Thorium
Titanium
Tungsten
Uranium
Vanadium
Yttrium
Zirconium

and other rare metals. Offers from producers should be accompanied by samples.

SYSTEMATIC COLLECTIONS

OF TYPICAL SPECIMENS

In sets of twenty-five up to fifteen hundred specimens. Prices $5.00 upwards per set, the average price for students' specimens being about twenty cents. We have supplied the leading institutions for thirty years, having lately completed a single order for over 60,000 specimens. Our material is the accepted standard both as to correct labeling and high quality.

Free Collection Catalog, containing lists and illustrations of General Mineral Collections, Series of Ores for Prospectors, Sets of Crystals, Series illustrating Hardness and other Physical Characters of Minerals, with Price List of Laboratory Material and Individual Specimens.

FOOTE MINERAL CO.,

Established 1876, by Dr. A. E. Foote.

W. M. FOOTE, Manager.

DEALERS IN

MINERAL SPECIMENS AND COMMERCIAL RARE MINERALS,

1317 Arch Street, Philadelphia.

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

Art. XXVIII.—*On the Ultimate Disintegration Products of the Radio-active Elements;* by Bertram B. Boltwood.

In a paper by Rutherford and Soddy,* the authors have called attention to the probability that an intimate knowledge of the composition of radio-active minerals will lead to the recognition and identification of the ultimate, stable products formed by the disintegration of the relatively unstable radio-active elements.†

It is an extremely impressive fact that it was from the somewhat meager information available on the occurrence of helium in radio-active minerals, and from the consideration of the data derived from the experiments of one of them on the nature of the expelled alpha particle, that in 1902 the same authors were enabled to make that brilliant prediction of the production of helium‡ which was afterwards confirmed by the experiments of Ramsay and Soddy.

The natural minerals represent chemical systems which are in most instances of extreme antiquity, their original formation having frequently taken place during the earliest geological periods of our planet. With the assistance of the data supplied by geology and mineralogy, it is often possible to assign the origin of a given mineral to some definite geological period and to arrange a series of different individuals roughly in the order

* Phil. Mag. (6), v, 576 (1903).

† "In the naturally occurring minerals containing the radio-elements these changes must have been proceeding steadily over very long periods, and, unless they succeed in escaping, the ultimate products should have accumulated in sufficient quantity to be detected, and should therefore appear in nature as the invariable companions of the radio-elements."—*Rutherford and Soddy, loc. cit.*

‡ Phil. Mag. (6), iv, 582.

of their production, obtaining in this manner an approximate knowledge of their relative ages. In dealing with the question of radio-active change, where the element of time is such an important factor in the solution of nearly every problem, the advantages to be derived from the careful study of the radio-active minerals can therefore scarcely be overestimated.

From a knowledge of the chemical properties and the crystallographic, optical and other physical properties of a given mineral specimen, together with an understanding of its occurrence and of the other mineral substances with which it is found associated, it is generally possible to definitely determine whether the mineral was formed simultaneously with the mass of material or geological formation in which it now occurs, or whether it is of more recent production, having originated through the action of percolating waters or of subterranean vapors or gases on some original constituent. In the former case, when all available data indicate that the formation of the mineral was coincident with that of the mass of rock in which it occurs, the mineral can be classed as primary; in the latter case, when it has apparently originated through the alteration of primary compounds, it can be considered as secondary. The term secondary can also be applied in a restricted sense to such minerals as occur in veins, where the general character of the vein indicates that it has originated through the formation of fissures in existing strata and that the contents of the vein is of an age inferior to that of the mass of rock by which it is bounded.

In applying these considerations to the greater number of minerals which have up to this time been observed to contain radio-active constituents, it may be considered as fortunate that these minerals occur under conditions which would seem to render the task of assigning the individual species to one or the other of the above classes a relatively simple one.

The most prominent radio-active mineral, uraninite, more commonly known as pitchblende, occurs both as a primary constituent of granitic rocks and also as a constituent of metalliferous veins cutting geological formations of a relatively recent geological period. When occurring in a granitic rock the uraninite is frequently quite perfectly crystalline in form and the rock itself is of the type called pegmatite; the most noted localities furnishing specimens of this primary uraninite being southern Norway, particularly in the neighborhood of Moss, North Carolina, Llano Co., Texas, and Connecticut. Prominent localities where uraninite occurs as a constituent of metalliferous veins are Johanngeorgenstadt, Marienberg and Schneeberg in Saxony, Joachimsthal and Přibram in Bohemia, Cornwall in England, and Colorado and South Dakota in the United States.

The term secondary uraninite will be used in referring to the material from these latter localities.*

Among the radio-active minerals other than uraninite which occur as primary constituents of pegmatite may be mentioned thorite, samarskite, fergusonite, aeschynite, euxenite, monazite and the recently described† thorianite. Associated with, and obviously resulting from the alteration of, the primary minerals through the action of percolating waters and other agencies, are secondary minerals, the more prominent of which are gummite, thorogummite, uranophane and autunite.

In considering the available data on the composition of radio-active minerals, with a view to discovering the ultimate disintegration products of the radio-elements, it is therefore necessary to give strict attention to the question of the primary or secondary origin of the individual specimens and the geological period at which they were formed. The nature of the associated minerals is also usually of considerable significance, since through them it is frequently possible to discover some clue to the conditions under which the mineral originated and some indication of the influences to which they have been subjected since they were first formed.

Lead.

In reviewing the various published analyses of minerals containing notable proportions of uranium, and particularly of those which are evidently of primary origin, one can not fail to be impressed by the frequent and almost invariable occurrence of lead as one of the other constituents. Out of a considerable number of analyses undertaken with the particular object of discovering whether or not lead was present, I have been unable to find a single specimen of a primary mineral containing over two per cent of uranium in which the presence of lead could not be demonstrated by the ordinary analytical methods. The same is moreover true of the secondary uranium minerals which have been examined, although in a single case, namely in a small specimen of uranophane from North Carolina, the proportion of lead was so low as to require the working up of a gram of material in order to conclusively demonstrate the presence of lead as a constituent.

Through a dawning appreciation of the significance of the persistent appearance of this element in uranium minerals, the writer was led to suggest in an earlier paper‡ that lead might prove to be one of the final, inactive disintegration products of uranium. All the data which have been obtained since that time point to the same conclusion.

* Hillebrand, this Journal, xl, 384 (1890).
† Dunstan and Blake, Proc. Roy. Soc. Lond. (A), lxxvi, 253 (1905).
‡ Phil. Mag. (6), ix, 613 (1905).

I have been particularly impressed by the information kindly supplied in a private communication by Mr. W. F. Hillebrand of the U. S. Geological Survey, a recognized authority on the analysis of uranium minerals, that so far as his experience goes he does not remember to have found uranium in any mineral without its being accompanied by lead, and he adds: "the association has often caused me thought."

Additional weight attaches to these experimental indications because of the theoretical considerations leading to a similar conclusion. It has been pointed out by Rutherford,* that if the alpha-ray particle consists of helium, since four alpha-ray products intervene between radium and the final, inactive substance radium-G, the indicated atomic weight of radium-G is sufficiently near to that of lead to be impressive. Thus one alpha particle is expelled by each of the atoms Ra, Ra-Em, Ra-A, Ra-C and Ra-F, making five particles in all. The loss of five alpha particles with an atomic weight of 4 from the atom of radium with an atomic weight of 225 would cause a reduction of this by $4\times5=20$ units, with the formation of a chemical element having an atomic weight of 205 or thereabouts. This is not far from the accepted atomic weight of lead, namely 206·9.

Thorium (*Rare earths*).

Another element which occurs quite commonly with uranium is thorium, and the common association of these two elements has been noted by Strutt and interpreted by him as indicating that thorium is possibly the parent of uranium.† Aside from the very doubtful hypothesis that the atomic weight of thorium is greater than that of uranium, his conclusions would seem open to serious objections. His statement that all thorium minerals contain readily detectable quantities of uranium, while some minerals containing notable quantities of uranium are comparatively free from thorium, is manifestly in accord with his experimental data, but it would appear that his thorium minerals containing uranium are all old minerals, while his uranium minerals containing no thorium are of relatively recent origin. If his theory is correct, the existence of very old minerals containing high percentages of uranium and no thorium should be possible, but that such minerals have been found is not indicated by any of the reliable analyses available. The experimental data offered by Strutt, as well as those to be derived from other sources, can all be much more consistently interpreted by the assumption that thorium is a disintegration product of uranium having a life considerably longer than that

* Silliman Lectures, Yale University, 1905. Not yet published.
† Proc. Roy. Soc. Lond. (A), lxxvi, 88 (1905).

of its parent and long as compared with the oldest of the known minerals. This hypothesis is supported by the circumstance noted by Strutt, that in general the minerals containing high proportions of thorium also contain a comparatively high proportion of helium, a point which will be referred to later in the course of this paper. Since the present knowledge of radio-active phenomena leads to the assumption that the average life of uranium is of the order of 2×10^9 years, while the average life of thorium is apparently in excess of that number, it seems scarcely reasonable to expect that minerals will be found which are sufficiently old for a state of equilibrium to have been reached between thorium and uranium. The production of a slowly changing disintegration product from a more rapidly changing parent is in no way contradictory to the disintegration theory, since a number of examples of this are at present recognized.* The common association of the other rare earths with thorium may indicate, as suggested by Strutt, that these are possible final products of the latter element.

Bismuth.

The occurrence of bismuth as a constituent of the more highly radio-active minerals is another significant indication of a possible end product. The proportion of bismuth which is present in the older radio-active minerals is, however, very small, so small indeed that its occurrence is but seldom detected in the ordinary course of analysis. It is only in treating considerable quantities of material for the extraction of polonium that the presence of bismuth becomes evident. This occurrence of bismuth in small quantities is suggestive of its formation from the disintegration, either of a parent having a relatively long life, or of one which is itself produced in only relatively small quantities. The former requirement would seem to be fairly well filled by thorium, in which case it is to be expected that in two minerals of equal age, the one containing the greater proportion of thorium would also contain the greater relative amount of bismuth. An opportunity has not yet been found for the experimental investigation of this question. The fact that the atomic weight of bismuth differs from the atomic weight of thorium by exactly 24 units, an even multiple of 4, is possibly significant.

Barium.

Another element which persistently appears as a minor constituent of uranium minerals is barium. Its production, if it is

* One example is the production of the active deposit from the thorium emanation, the parent with a half-value period of less than one minute, the product with a half-value period of eleven hours.

actually a disintegration product, is certainly slow, for only very small relative amounts of it are found in some comparatively old minerals. In primary minerals the amount of lead present is always greatly in excess of the barium, which occurs only in traces made evident in the separation of the radium from considerable quantities of material. As in the case of bismuth, the barium might be produced either from a slowly disintegrating parent or from a radio-active body existing only in comparatively small amounts in the radio-active system. Certain data, to be published later by the writer, have been obtained which seem to indicate that the amount of actinium in a radio-active mineral is dependent on the amount of uranium present, thus suggesting that uranium is the parent of actinium as well as of radium, but other results lead to the conclusion* that actinium is not a direct result in the same sense as is radium. The quantity of actinium produced in a radio-active mineral is apparently small as compared to the radium, and it may therefore be possible that the barium present is a final product of the actinium.

Hydrogen.

A point which has caused much speculation on the part of mineralogists is the apparent hydration of the greater number, if not all, of those minerals which are now known to contain radio-active constituents. That this state of affairs is in some way connected with the disintegration processes taking place in these compounds would not appear impossible, since the production of such an elementary substance as hydrogen as one of the products of the radio-active decay of the atoms of elements of high atomic weight is in fact suggested by much of the data on the nature of the expelled alpha particles.† It would seem possible that the difference in ionizing power, of the power of penetration, etc., shown by the alpha particles from certain of the radio-active types of material may perhaps be due to a difference in the mass of the projected particle, and that the occurrence of notable quantities of water in the primary radio-active minerals, which is otherwise most difficult to explain, may be considered as indicating that hydrogen is in fact one of the disintegration products, originating as an alpha-ray particle from one or more of the numerous radio-active substances which have already been identified. The origination of hydrogen in a mineral containing oxidized constituents would in all probability lead to the reduction of the more readily reducible of these with the consequent production of water.

* Rutherford and Boltwood, this Journal, xx, 56 (1905).
† Rutherford, "Radio-activity," p. 328 and elsewhere.

In the greater number of instances where water is found present in these minerals, it is quite impossible to explain how it could have penetrated into them from without, since their close-grained and impervious nature is impressively indicated by the very notable quantity of helium which they have retained. Moreover non-radio-active minerals which occur associated with the radio-active species, and which have been subjected to the same external influences, are often quite anhydrous, e. g., apatite, magnetite, etc. The mineral thorite has been called to the attention of the writer by Professor S. L. Penfield. This mineral frequently occurs in very perfect crystals, which however exhibit only the optical properties of an isotropic and amorphous compound. This species has been long regarded as having undergone alteration, but that the causes of the alteration existed within and not without the crystals is, I believe, a new and somewhat novel explanation.

It is a significant fact that results obtained* in the examination of certain radio-active minerals indicate that hydrogen occurs as one of the gaseous constituents of many of these compounds. A further interesting point bearing on this question is mentioned by Hillebrand,† who observed that when uraninite was mixed with sodium carbonate and fused in an atmosphere of carbon dioxide, the lead present was apparently entirely reduced and collected in globules. Mixtures of corresponding proportions of lead oxide (litharge) and U_3O_8 or UO_2, when treated in an identical manner, showed no reduction of the litharge to metallic lead. This distinctive difference in behavior is strongly indicative of the presence of hydrogen as a constituent of uraninite.

Argon.

Results obtained by Ramsay and Travers‡ may further indicate that another of the disintegration products of radio-active substances is the inert gas argon. It is stated by these authors that most minerals which evolve helium also evolve argon in small quantity. It may not be impossible that some of the rayless changes which have been observed by Rutherford to take place in radio-active bodies, may be accompanied by the expulsion of alpha particles consisting of argon, which owing to their relatively high mass are projected at too low velocities to cause ionization of the surrounding gases and to permit

* Ramsay, Collie and Travers, Jour. Chem. Soc., Lond., lxvii, 684 (1895), state that hydrogen in varying quantities was evolved by yttrotantalite, samarskite, hielmite, fergusonite, tantalite, monazite, xenotime, columbite, perofskite, euxenite, orthite, gadolinite and cerite. Also Ramsay, Proc. Roy. Soc. Lond., lix, 325 (1896).

† Bulletin of the U. S. Geological Survey, No. 78, p. 59 (1891).

‡ Proc. Roy. Soc. Lond., lii, 316 (1898).

their detection by the ordinary electrical methods. It has been pointed out by Rutherford* that the kinetic energy of certain alpha particles approaches quite closely to the critical value below which no ionization would be produced. It is moreover quite interesting that the assumption of a difference of atomic mass of 40 units between certain successive radio-active transformation products would greatly facilitate their assignment to vacant positions in the periodic system of the elements.

Composition of Uraninite.

The suggestions offered in the foregoing pages as to the possible nature of some of the disintegration products resulting from the process of radio-active change can be more clearly understood, and the basis of fact from which they have been derived can be more correctly appreciated, by a consideration of some of the results which have been obtained in the analysis of radio-active minerals.

The most accurate and reliable of the available data on the composition of uraninite have been published by Hillebrand.†

TABLE I.

Locality Number.	Glastonbury, Conn.					Branchville, Conn.			Colo.	N. Carolina.	
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
UO_3	22·08	23·35	22·22	26·48	23·03	13·27	21·54	14·00	25·26	50·83	44·11
UO_2	59·13	58·01	59·31	57·43	59·93	72·25	64·72	70·99	58·51	39·31	46·56
Total Uranium	70%	70	70	72	72	74	75	74	72	77	77
PbO	3·14	3·24	3·07	3·26	3·08	4·35	4·34	4·35	0·70	4·20	4·53
ThO_2	----	----	----	9·79	----	7·20[2]	6·93	6·52[2]	0·0	2·78	
Total rare earths	9·57	10·24	10·31	10·37	11·10	7·20	7·26	6·52	7·81	3·74	3·04
N_2 [1]	....	....	- --	...	2·41	....	....	2·63	0·15	0·37	
H_2O	0·97	....	....	0·61	0·43	0·68	0·67	0·68	1·96	1·21	
Sp. G.	9·12	9·05	....	9·58	9·62	9·73	9·56	9·35	8·07	9·08	9·49

Various important details such as the general character and appearance of the different samples and the indication of alteration from external causes in a number of specimens will be found in Hillebrand's papers.

Blank spaces in the table signify that the indicated constituent was not determined.

[1] Hillebrand assumed that the inert gas present was nitrogen and the percentages of this element shown in the table are calculated on the basis of that assumption. By dividing these numbers by 7 a maximum value for the helium separated is obtained.

[2] $ThO_2 + ZrO_2$?

The results of his analyses are given in a condensed form in Table I.

* Phil. Mag., July (1905).

† Bulletin of the U. S. Geological Survey, No. 78, p. 43, 1891; this Journal, xl, 384 (1890); ibid., xlii, 390 (1891).

Neglecting for the present the results under IX and XXII, which are types of secondary uraninites, it will noticed in an examination of the numbers given in Table I that—

1. In specimens from the same general locality, viz.: from Connecticut, from Norway and from North Carolina, a rough proportionality is shown between the content of uranium and the content of lead, rare earths, helium (nitrogen) and water. A still more striking relation appears to exist between the proportion of uranium in the form of the lower oxide, UO_2, and the amount of helium (nitrogen). This was remarked by Hillebrand, who makes the following statement* in connection with the results obtained from the analysis of the first eighteen samples:

"Throughout the whole list of analyses in which nitrogen has been estimated the most striking features is the apparent relation between it and the UO_2. This is especially marked in the table of Norwegian uraninites recalculated†, from which the rule might almost be formulated that, given either nitrogen or UO_2 the other can be found by simple calculation. The same ratio is not found in the Connecticut varieties, but if the

TABLE I.

			Norway.				Texas.	S. Carolina.	Canada.	Saxony.
XII	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI.	XXII.
30·63	25·36	22·04	32·00	35·54	42·71	26·81	44·17	----	41·06	59·30
46·13	50·74	43·03	43·88	43·38	24·18	44·18	20·89	----	34·67	22·33
66	66	57	65	68	56	61	55	71	65	68
9·04	10·06	8·58	9·46	9·44	10·54	10·95	10·08	3·58	11·27	6·39
6·00	8·48	----	8·98	6·63	----	4·15	6·39	1·65	6·41	0·0
7·62	9·03	8·43	10·48	8·09	13·42	13·87	19·19	10·25	10·49	0·0
1·17	1·28	1·08	1·03	1·08	----	1·24	0·54	----	0·86	0·02
0·74	0·73	0·74	0·77	0·79	1·23	----	1·48	----	1·47	3·17
8·89	9·14	8·32	8·96	8·93	7·50	----	8·29	----	----	6·89

Of the samples from Norway XII was from Anneröd, XIII and XIV from Elvestad, XV from Skaartorp, XVI from Huggenäskilen, and XVII and XVIII from Arendal. Sample XIX was from Llano Co., Texas, XX from Marietta, South Carolina, XXI from Villeneuve, Canada, and XXII from Johanngeorgenstadt, Saxony.

determination of nitrogen in the Branchville mineral is to be depended on, the rule still holds that the higher the UO_2 the higher likewise is the nitrogen. The Colorado and North Carolina minerals are exceptions, but it should be borne in mind that the former is amorphous like the Bohemian and possesses the further similarity of containing no thoria, although zirconia may take its place, and the North Carolina material is

* This Journal, xl, 391 (1890). † Excluding the insoluble matter.

so much altered that its original condition is unknown." This generalization can apparently be extended to include lead also.

2. When the analyses of samples from the same actual locality are compared it will be evident that, in general,

a) The content of rare earths increases with the amount of lead present. This is most strikingly shown in the groups I–V, VI–VIII, XIII–XIV and XVII–XVIII. The simultaneous variation of thorium is also indicated somewhat imperfectly in those instances where this constituent was separately determined.

b) That in those specimens having the highest specific gravity (V and VIII) the proportion of helium compared with the lead present is greatest. It is in general to be expected that the denser and therefore less porous material would retain a greater proportion of the helium formed within it. The low proportion of gas compared with lead in X and XIX might well be due to the high emanating power of the former* and the greater porosity of the latter indicated by its low density. It is moreover interesting to note that those specimens (X, XIX, XXI) containing disproportionately large amounts of water contain a relatively low amount of helium compared with the lead present. It is possible that these minerals were sufficiently porous to permit the entrance of water from without while at the same time a part of the helium formed has escaped from within them.

It is evident that, in Table I, a lack of agreement exists between the proportion of lead and rare earths and the proportion of helium in the Connecticut material and the proportions of the corresponding constituents in the Norwegian samples. In the latter the amounts of lead and rare earths as compared with the gas present are much greater than in the former. This can be explained by assuming that the Norwegian minerals are considerably older than the American varieties, and that the Norwegian specimens examined by Hillebrand have in some manner lost a large part of their helium. The geological data available on the relative ages of the American and Norwegian occurrences, while not entirely in accord with the assumption of such a great difference in age, would not appear to be sufficiently definite to preclude such a possibility.

In considering the bearing of the results of the analyses of the two secondary uraninites, IX and XXII, on the general theories proposed in this paper, it is evident that the presence

* Phil. Mag. (6), ix, 609.

of the low proportion of lead and helium, and the practical absence of thorium in IX, is quite in accord with the geological indications that this material is of an age greatly inferior to that of the primary uraninites. In XXII the very notable amount of lead shown by the analysis would seem to offer no serious obstacle to the theory, since this material occurs intimately associated with the sulphide of lead and other similar minerals, and the massive and amorphous form in which it is found would indicate that the conditions under which it was originally deposited were not favorable to the separation of a pure uranium compound. The statement of Hillebrand* that nitrogen (helium) and the rare earths were practically absent in specimens of secondary uraninite from Pribram, Joachimsthal and Johanngeorgenstadt, which he examined, is also of interest in this connection. The experience of Debierne† in separating actinium from a secondary uraninite of this character, is, however, indicative of the existence of small amounts of thorium in these minerals.

Other Radio-active Minerals.

In the table which follows (Table II) will be found some data compiled from various sources on the composition of a number of primary and secondary radio-active minerals.

As bearing on the topic under discussion it is interesting to note the following :—

1. The greatest proportion of helium with respect to the uranium and lead present has been observed in those primary minerals which have the lowest emanating power and the highest specific gravity, i. e., in the most compact and least porous minerals. Examples are furnished by thorianite, fergusonite, samarskite and monazite. (Of the varieties of thorite, much greater proportions of helium have been observed in the variety known as orangite, which has also the greatest density.)

2. Greater proportions of lead and helium with respect to uranium are found in those primary minerals which occur in the oldest geological formations. This point is well illustrated by thorianite, which is found in Ceylon in a geological formation which is probably of the Archean period.

3. The primary minerals containing the greatest proportion of thorium are in general the most hydrated.

In considering the secondary radio-active minerals certain probable conditions must be recognized. Where these minerals are formed by the alteration of primary minerals *in place*, namely, where the primary mineral is acted on by underground

* Bulletin U. S. Survey, No. 78, p. 72.
‡ Compt. rend., cxxx, 906 (1900).

TABLE II.

PRIMARY MINERALS.

Species. Locality.	ThO_2	UO_2	PbO	H_2O	He	Reference.
Thorite, Hitterö, Norway	48·66	9·00[1]	1·26	10·88	X^a	Dana, p. 488
Mackintoshite, Llano Co., Tex.	45·30	22·40	3·74	4·31	X^b	A_1
Yttrialite, Llano Co., Tex....	10·85	1·64	0·80	0·32	X^c	A_2
Thorianite, Ceylon	78·86	....[2]	2·59	X^d	0·39%	A_3
Samarskite	....[3]	10–13%	....	3–1%	X^e	
" (?) Colorado	3·64	4·02	0·72	1·58	?	Dana, p. 740
Anneródite, Anneröd, Nor. ...	2·37	16·28	2·40	8·19	?	Dana, p. 741
Euxenite	....[3]	5–12%	0·92	4·71	?	Dana, p. 744
Hielmite, Falun, Sweden	?	2·34[4]	0·21	2·23	X^e	Dana, p. 742
Polycrase, Slättakra, Nor.	3·51	18·45	0·92	4·71	X^e	Dana, p. 745
Fergusonite, Llano Co., Tex...	0·83	7·05[5]	1·43	2·02	?	Dana, p. 730
" ..	?	3·81[4]	0·16	?	0·03	A_4
Xenotime, Narestö, Sweden...	2·43	3·48[4]	0·68	1·77	X^e	Dana, p. 749
Monazite, North Carolina	5·00	0·40[6]	tr.	0·20	X^e	

SECONDARY MINERALS.

		UO_3				
Gummite, North Carolina	....[7]	75·20	5·57	10·54	?	Dana, p. 892
Thorogummite, Llano Co., Tex.	41·44	22·43	2·16	7·88	?	A_5
Carnotite, Colorado	0·0	52·25	0·25	3·06	0[8]	A_6
Uranophane, North Carolina..	....[9]	66·67	0·60	12·02	?	Dana, p. 699

[1] U_3O_8. [2] UO_2 6·03 + UO_3 9·07.

[3] Hofmann and Strauss (Berichte, xxxiii, 3126) state that they found both thorium and lead in samarskite and in euxenite.

[4] UO_3. [5] UO_3 and UO_2.

[6] The composition of monazite given above is derived from experiments of the writer.

[7] Specimens of gummite from North Carolina analyzed by the writer have been found to contain from 2 to 3 per cent. of thoria.

[8] It is stated by Adams (this Journal, xix, 321 (1905) that helium is absent from this mineral, which is to be expected since it is highly porous and of recent formation.

[9] Samples of this material have been examined by the writer in which no thorium could be detected.

X^a Helium has been found in the variety of thorite known as orangite.

X^b Hillebrand's experiments suggest the presence of helium in this mineral.

X^c Including this species among the primary minerals is possibly open to objection. Hillebrand's experiments would seem to indicate that it contains from 1^{cc} to 2^{cc} of helium per gram.

X^d The analyses of Dunstan and Blake (see Ref.) do not indicate the presence of water, but several tests made by the writer, on samples kindly supplied by Mr. Geo. F. Kunz, suggest the presence of water in quite notable quantities.

X^e The occurrence of helium in samarskite, hielmite, polycrase, xenotime, monazite, orangite, and other radio-active minerals is described in papers by Ramsay, Collie and Travers (Jour. Chem. Soc. Lond., lxvii, 684) and Ramsay and Travers (Proc. Roy. Soc. Lond., lx, 442).

A_1 W. F. Hillebrand, this Journal, xlvi, 101 (1893).
A_2 Hillebrand, this Journal, xiii, 195 (1902).
A_3 Dunstan and Blake, Proc. Roy. Soc. Lond. (A), lxxvi, 253 (1905).
A_4 Ramsay and Travers, Proc. Roy. Soc. Lond., lii, 316 (1898).
A_5 Hillebrand and Mackintosh, this Journal, xxxviii, 480 (1889).
A_6 Hillebrand and Ransome, this Journal, x, 120 (1900).

waters, etc., with the removal of certain constituents and the substitution of others originally dissolved in the waters, the resulting hydrated residue will in some cases consist of a mixture of several different chemical compounds and its general composition will not correspond to any definite formula, but will depend on chance and the accidental local conditions. An excellent example of a secondary product of this character is afforded by the mineral known as gummite, which occurs as an alteration product of the North Carolina uraninites. Samples of this mineral from the Flat Rock mine have been examined by the writer, in which great variations in the proportions of lead, thorium and uranium present were observed in samples removed from different parts of the same comparatively small specimen. The mineral known as uranophane from the same locality shows corresponding variations in composition. Both these substances are amorphous in structure but very frequently occur with a crystalline form as pseudomorphs after the original uraninite. It is obvious that these facts must be considered in attempting to arrive at any conclusions from a chemical examination of these materials.

In other cases the percolating waters undoubtedly dissolve the more readily soluble components of the primary minerals and deposit them again as definite, crystalline compounds of a relatively high degree of purity. Examples of this sort are afforded by such minerals as torbernite [$Cu(UO_2)_2P_2O_8 \cdot 8H_2O$], autunite [$Ca(UO_2)_2P_2O_8 \cdot 8H_2O$,], uranocircite [$Ba(UO_2)_2P_2O_8 \cdot 8H_2O$], zeunerite [$Cu(UO_2)_2As_2O_8 \cdot 8H_2O$], uranosphaerite [$(BiO)_2U_2O_7 \cdot 3H_2O$], and a considerable number of others. The examination of minerals of this character will probably afford data of considerable value on the nature of the ultimate disintegration products of uranium.

The mineral mackintoshite is quite possibly of secondary origin, but owing to some doubt in the matter it has been placed among the primary minerals. It may represent a variety of thorite, containing originally a considerable proportion of uranium, which has undergone alteration owing to the radio-active processes which have taken place within it. The evidence is strongly in favor of the view that the thorogummite has been formed from the alteration of the mackintoshite through external causes.

Any definite conclusions at present as to the formation of carnotite are quite impossible. Its composition and occurrence are both so unique that little or no analogy with other known uranium compounds can be detected. It seems highly probable, however, that its age is not relatively very great and its general composition, *e. g.* the low amount of lead present and the practical absence of thorium and helium, is quite in accord with such a conclusion.

An interesting radio-active mineral has been described by Danne.* This substance is stated to be a phosphate of lead, or pyromorphite, containing quantities of radium equivalent to about 6 per cent of uranium. It is asserted, however, that no uranium is present in the mineral, although considerable deposits of uranium minerals are known to exist at no very great distance in the same region where it occurs. According to Danne, the pyromorphite is found in fissures through which underground waters containing radium salts are constantly percolating, and he suggests that the radium contained in the mineral is derived from the water. It might also be conjectured that the lead of the mineral has resulted from the disintegration of radium, the radium itself having been formed from the disintegration of uranium in the neighboring deposits.

Occurrence of Minerals.

It would seem possible that some general data on the disintegration products of radio-active substances might be derived from the study of the conditions under which the radio-active minerals occur in nature. The following suggestions may perhaps be of interest in this connection. The primary minerals found in the pegmatitic dikes include uraninite, thorite, fergusonite, aeschenite, euxenite, columbite and monazite, all of which, with the exception of columbite,† probably contain thorium in greater or smaller proportions. The theory generally accepted by geologists is that the pegmatites were formed under conditions of so-called hydro-igneous fusion, involving high temperatures and the presence of considerable water vapor which was prevented from escaping by the high pressure due to incumbent masses of rock of great thickness. Assuming the prior existence of considerable deposits of uranium compounds at great depths, it would appear probable that in an upheaval of deep-lying material, with the intrusion of the plastic magma into the upper layers from below, the conditions would be favorable to the separation of the various constituents of the already partially disintegrated uranium with the production of new minerals representing new combinations of the various elements present. Thus some of the uranium might separate out as the oxide (uraninite), either quite free from other elements or with admixtures of other isomorphous oxides (thorium oxides and other rare earth oxides), while the thorium might be greatly concentrated in the form of such minerals as thorite and thorianite, containing mixtures of variable propor-

* Compt. rend., cxl, 241 (1905).

† The very common association of radio-active elements with niobium, tantalum, etc., in minerals is possibly significant of some ultimate relation between them.

tions of uranium and the rare earths. Others of the rare earths present might be themselves concentrated to form such minerals as allanite and gadolinite, compounds containing but relatively small proportions of the radio-elements.

When uraninite is found in metalliferous veins the general indications point to its transportation hither from greater depths by thermal waters and its deposition at a temperature considerably lower than that existing in the plastic pegmatite. The association of the secondary uraninites with the sulphides of iron, copper, lead, bismuth and other metals is indicative of conditions of deposit unfavorable to the simultaneous production of rare earth minerals, which have never been observed to occur under similar conditions in any locality.

The mode of occurrence of radio-active minerals would therefore appear to offer certain valuable data on the processes taking place in the radio-elements and the products formed by their disintegration.

Origin of Elements.

If it can be ultimately demonstrated that lead, bismuth, barium, hydrogen and argon, or any one of them, actually result from the disintegration of uranium, an interesting question which naturally arises will be: Have the quantities of these chemical elements already existing been produced wholly in the same manner? Any discussion of this problem at the present time would certainly be premature, but the time may not be very far remote when this question will deserve serious consideration.

Summary.

Various data have been presented which are interpreted as indicating that the ultimate disintegration products of the radio-elements may include lead, bismuth, barium, the rare earths, hydrogen and argon.

The writer is fully conscious of the meagerness of the data upon which the hypothesis of the production of these substances is founded, but the suggestions are made in the hope that the attention of other investigators may be directed to the possibilities offered by a careful study of the composition and occurrence of the radio-active minerals, and that their interest may be sufficiently awakened to induce them to independently undertake the experimental investigation of the theories which have been suggested.

139 Orange St., New Haven, Conn.
August 16, 1905.

ART. XXIX.—*The Use of the Rotating Cathode for the Estimation of Cadmium taken as the Sulphate;* by CHARLES P. FLORA.

[Contributions from the Kent Chemical Laboratory of Yale Univ.—cxxxix.]

IN a recent paper from this laboratory* has been described the application of the rotating cathode to the rapid estimation of copper, silver and nickel; and, in a later paper,† its fitness for the estimation of cadmium as well as several other metals has been shown. The object of the present investigation has been to more thoroughly study the conditions under which cadmium may be estimated by this means. The apparatus used was that described in the previous papers. Since it had already been shown‡ that cadmium taken in the form of the sulphate can be estimated by deposition of a solution slightly acidulated with sulphuric acid, this formed the natural point of departure.

I. *In Solutions containing Sulphuric Acid.*

A solution of cadmium sulphate was prepared, containing approximately 16·6 grams of the salt to the liter of water. Portions of this solution were carefully measured from a burette, diluted to the desired volume, a few drops of dilute sulphuric acid (1:4) added, the proper connections made and the electrolysis conducted as previously described. The following were the results obtained upon two different solutions:

SOLUTION A.

No. of Exp.	Sol. taken. cm^3.	H_2SO_4. (1:4) drops.	Time. min.	Cur't read. = amp.	$N.D._{100}$ amp.	E.M.F. approx. volts.	Cd. found grm.
1.	15	5	18	0·4–1·0	1·2–3·0	8	0·1111
2.	15	5	10	0·4–0·5	1·2–1·5	8	0·1090
3.	15	5	16	0·4–0·9	1·2–2·7	8	0·1115
4.	15	7	35	0·5–1·0	1·5–3·0	8	0·1117
5.	15	12	25	1·0–1·5	3·0–4·5	8	0·1115
6.	15	10	35	1·0–1·5	3·0–4·5	8	0·1120
7.	15	18	30	1·5–2·0	4·5–6·0	8	0·1119
8.	15	15	25	1·5–2·0	4·5–6·0	8	0·1117
9.	30	Indef.	15	3·0–4·0	9·0–12·0	8	0·2235
10.	20	12	35	2 0–3·0	6·0–9·0	8	0·1491
11.	15	Indef.	60	2·0	6·0	8	0·1120

In experiments numbered 1 to 4, the liquid at the end of the period indicated showed traces of cadmium remaining, but in the seven experiments following these the cadmium was all deposited upon the cathode in a satisfactory condition. These

* Gooch and Medway, this Journal [4], 320 (1903).
† Medway, this Journal [4], xviii, 56 (1904). ‡ Loc. cit.

results were therefore taken as indicating the standard of the solution used, the mean of the series showing the presence of 0·007454 grm. of cadmium in each cubic centimeter of the solution.

In a second solution which it became necessary to standardize the following results were obtained:

SOLUTION B.

No. of Exp.	Sol. taken. cm.	Time. min.	Cur't read. = amp.	$N.D_{100}$ amp.	E.M.F. vts.	Cd. found. grm.
1.	20	27	1·0–1·5	3·0– 4·5	7·9	0·0816
2.	25	30	2·0–3·0	6·0– 9·0	7·9	0·1018
3.	25	55	2·5–4·0	7·5–12·0	7·6	0·1019
4.	30	25	2·0–2·5	6·0– 7·5	12·0	0·1224
5.	30	20	1·0	3·0	7·8	0·1223
6.	30	10	1·5–2·5	4·5– 7·5	7·8	0·1226

The mean of these six experiments gives a value of 0·10194 grm. of cadmium for every 25^{cm^3} of the solution, or 0·0040776 grm. for each cubic centimeter. This value was taken as the standard whenever this solution was used.

One point which was not mentioned in the former paper* on the estimation of cadmium by this method, but which is of much importance, is that of dilution. The earlier experiments in this work were performed at a dilution of from 65^{cm^3} to 75^{cm^3}. Much trouble was experienced, however, at this dilution; for the last traces of the metal were driven from the solution only with extreme difficulty and with much loss of time, as may be noted by comparing the time interval of most of the experiments with the shorter interval of the last two experiments of the second series, where the dilution was 45 to 50^{cm}. Moreover it was found advisable, in order to avoid mechanical loss, to deposit not more than 0·2 grm. to 0·25 grm. of the metal upon the cathode, while even smaller quantities are to be preferred. The current density must also be kept within the limits indicated; for otherwise a spongy deposit may result. Cadmium seems to be especially liable to the formation of these spongy, unweighable deposits, and the greatest difficulties experienced in this investigation have come from this behavior of the metal.

The best condition, therefore, may be briefly summarized as follows: Cadmium sulphate, equivalent to not more than $0·2^{cm}$ to 0·25 grm. of the metal, is dissolved in 45^{cm^3} to 50^{cm^3} of water; ten to fifteen drops of dilute sulphuric acid are added; and the proper connections made and the solution subjected to electrolysis as described, fifteen minutes being sufficient time for the complete deposition of the metal upon the cathode. It

* Loc. cit.

is not necessary to heat the liquid, as the passage of such large currents soon heats it sufficiently. When electrolysis is complete, the excess of sulphuric acid may be destroyed with a slight excess of ammonia water, the current broken, and the cathode removed, thoroughly rinsed with water and alcohol, and dried by waving over a free flame. If the deposit is not spongy the drying is a matter of only a few moments, and there is no danger of oxidizing the metallic deposit. If it is preferred, the current may be reduced by interposed resistance, the rotation stopped, and the liquid readily siphoned without danger of injuring the metallic coating.

II. *In Solutions containing Acetates.*

The next method to be studied in its application to the rotating cathode was the use of solutions containing acetates, as recommended by Edgar F. Smith. Originally, Smith used a solution obtained by dissolving cadmium oxide in acetic acid* but later found that the electrolysis proceeded equally well in solutions containing the nitrate, chloride or sulphate of cadmium with an excess of sodium acetate.† In the study of the application of this method to the estimation of cadmium, taken as the sulphate, upon the rotating cathode, two methods of proceeding were followed, both of which had been previously used by Exner‡ in his work upon the rotating anode. In series A, of the experiments following, measured amounts of cadmium sulphate solution were run off from a burette, the indicated amount of sodium acetate was added in solution, a small amount of potassium sulphate was added to increase the conductivity of the solution, the whole diluted to the desired volume and electrolysis conducted as with the solution containing sulphuric acid. In series B, the cadmium in the measured solution was precipitated as the hydroxide with a sodium hydrate solution, the precipitate dissolved in a very slight excess of acetic acid, potassium sulphate added as before, and the solution subjected to electrolysis.

SERIES A.

No.	Cd. taken. grm.	$NaOC_2H_3O$. grm.	K_2SO_4. grm.	Cur't read. = amp.	$N.D_{100}$. amp	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0·1864	1·5	0·5	2·0	6·0	8·0	.	(§)	----
2.	0·1491	2·0	1·0	1·5	4·5	8·0	15	(‖)	----
3.	0·1118	0·5	1·0	1·0	3·0	8·0	20	0·1121	+0·0003
4.	0·1491	1·5	0·5	0·9	2·7	8·0	15	0·1494	+0·0003
5.	0·1491	1·5	0·5	0·9	2·7	8·0	15	0·1496	+0·0005
6.	0·1223	1·5	0·5	0·75	2·25	7·5	20	0·1237	+0·0014

* Ber., xi, 2048 (1878). † Am. Ch. J., ii, 41 (1880).

‡ J. Am. Ch. Soc., xxv, 896 (1903).

§ Did not weigh, as precipitate was non-adherent. Current too high for quantity of cadmium present. ‖ Deposits spongy and blistered. Too much electrolyte present.

SERIES B.

No.	Cd. taken. grm.	NaOH. grm.	K_2SO_4. grm.	Cur't = amp.	$N.D_{100}$ amp.	E.M.F. vts.	Time. min.	Cd. found. grm.	Error. grm.
1.	0·1491	excess	0·5	1·25	3·75	8·0	10	0·1496	+0·0005
2.	0·1491	0·2	0·5	0·8	2·4	8·0	15	0·1491	±0·0000
3.	0·1491	0·2	0·5	0·8	2·4	8·0	15	0·1493	+0·0002
4.	0·1223	0·5	0·2	1·0	3·0	12·0	20	0·1223	±0·0000
5.	0·1223	0·5	0·2	1·0	3·0	12·0	20	0·1223	±0·0000
6.	0·1223	0·2	0·5	1·25	3·75	7·5	10	0·1227	+0·0004

In both series the volume of the solution was about 60$^{cm^3}$ to 65$^{cm^3}$. The sixth experiment in each series will indicate the result when the greater concentration of 45$^{cm^3}$ to 50$^{cm^3}$ was tried. In these cases the precipitate showed a tendency to sponginess, which was more noticeable in series A. At the greater dilution, the deposition of the cadmium proceeds rapidly and satisfactorily; the deposit is rather crystalline, fairly compact, and easily washed, so that the method forms one of the very best where the cadmium is taken in the form of the sulphate: the chloride and nitrate behave differently and will be treated later. The second modification seemed to give deposits more satisfactory than the first. Certain cautions, however, are to be observed. Not more than 0·1500 grm. may safely be estimated; the normal current density should not exceed 3·0 amperes if a spongy deposit is to be avoided; and, for the same reason, a large excess of electrolytes is to be avoided.

III. *In Solutions containing Cyanides.*

The deposition of cadmium from a solution of the double cyanide has always been very satisfactory, and the results with the rotating cathode were in complete accordance with previous work on this method. The range of conditions of current and quantity of electrolyte is broad, the deposit is a beautiful silvery plate, so compact as to be rubbed off only with difficulty, which dries very quickly; and although the complete deposition of the metal is not so rapid as it is from solutions containing sulphates or acetates, it is sufficiently rapid. Care should be taken to avoid foaming of the solution, as this retards somewhat the deposition of the final traces of cadmium. Generally, a volume of 65$^{cm^3}$ to 70$^{cm^3}$ was found most satisfactory. The solution was run off into a beaker of convenient size, the cadmium precipitated with sodium hydroxide, and the precipitate redissolved in potassium cyanide. The following results were obtained:

No.	Cd. taken. grm.	NaOH. grm.	KCN. grm.	Cur't read = amp.	$N.D_{100}$. amp.	E.M.F. vts.	Time. min.	Cd. found. grm.	Error. grm.
1.	0·1491	1·5	0·5	2·5	7·5	8	35	0·1498	+0·0007
2.	0·1491	1·0	0·5	2·5–4·5	7·5–13·5	8	30	0·1490	−0·0001
3.	0·1223	1·5	1·0	2·5	7·5	8	35	0·1225	+0·0002

IV. *In Solutions containing Pyrophosphates.*

Brand* has recommended the use of a solution containing sodium pyrophosphate for the electrolytic estimation of metals, among others, cadmium: and the fitness of this solution for use with the rotating cathode was now studied. In each case the cadmium was precipitated with the indicated amount of sodium pyrophosphate, the precipitate dissolved in an excess of ammonium hydroxide (series A), phosphoric acid of 1·7 specific gravity (series B), sulphuric acid (series C), or hydrochloric acid (series D), and subjected to the action of the current. The volume of the solution was 60$^{cm^3}$.

While fairly accurate results may be obtained, the method is neither so accurate as those previously described, nor are the conditions so flexible. Particular care must be used to avoid too large a current, as a spongy deposit may result. The following were the results obtained:

Series A.

No.	Cd. taken. grm.	$Na_4P_2O_7$. grm.	NH_4OH.	Cur't = amp.	$N.D_{100}$. amp.	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0·1491	0·5	15$^{cm^3}$ (1 : 4)	1·0–1·5	3·0–4·5	8	15	0·1498	+0·0007
2.	0·1491	0·5	excess.	0·4	1·2	8	15	0·1489	−0·0002
3.	0·1864	0·5	15$^{cm^3}$ (conc.)	0·7	2·1	8	15	0·1869	+0·0005

Series B.

			H_3PO_4 (1·7 sp. gr.)						
4.	0·1491	1·0	1·0$^{cm^3}$.	1·0	3 0	8	30	0·1496	+0 0005
5.	0·1864	1·0	1·0 "	1·0–1·5	3·0–4·5	8	30	0·1857	−0·0006
6.	0·1491	1·0	1·0 "	1·0	3·0	8	30	0 1493	+0·0002

Series C.

			H_2SO_4.						
7.	0·1491	1·0	2$^{cm^3}$ (1 : 4)	2·0–2·5	2·0–7·5	8	30	0·1501	+0·0010
8.	0·1864	0·5	excess.	1·0–2·0	3·0–6·0	8	35	0·1862	−0·0002

Series D.

			HCl.						
9.	0·1491	0·5	slt. excess.	1·0	3·0	8	37	0·1499	+0·0008
10.	0·1491	0·5	" "	1·0	3·0	8	36	0·1486	−0·0005

* Z. anal. Ch. xxviii, 581 (1889).

In Nos. 1 and 3 a small amount of dilute sulphuric acid was added to increase the conductivity of the solution, but the time was not reduced thereby, while the resulting deposit was slightly spongy.

In No. 5 the cadmium was not quite all precipitated.

In No. 7 the precipitate was spongy.

V. *In Solutions containing Phosphates.*

The use of a solution containing the orthophosphates dissolved in phosphoric acid has been recommended by Smith*, and this solution was next tried. The following results will show the scope of the modifications tried:

No.	Cd. taken. grm.	HNA_2PO_4. grm.	H_2PO_4 (1:7) cm.	Total vol. cm.	Cur't.= amp.	$N.D_{100}$. amp.	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0·1491	0·5	1·0	75	1·0–1·2	3·0– 3·6	8	20	0·1477	−0·0014
2.	0·1491	0·5	5·0	75	2·0–2·5	6·0– 7·5	8	23	0·1496	+0·0005
3.	0·1491	0·5	5·0	75	2·0–1·5	6·0– 4·5	8	30	0·1508	+0·0017
4.	0·1491	0·5	3·0	75	2·5	7·5	12	25	0·1502	+0·0011
5.	0·1491	0·5	4·0	75	2·5	7·5	8	25	0·1485	−0·0006
6.	0·1491	9·5	2·0	75	2·5	7·5	12	35	0·1501	+0·0010
7.	0·1864	0·25	2·0	75	2·0–3·0	6·0– 9·0	12	40	0·1861	−0·0003
8.	0·1491	0·3	1·5	75	3·5	10·5	12	30	0·1502	+0·0011
9.	0·1019	0·25	5·0	75	2·5–3·0	7·5–9·0	7·8	30	0·1024	+0·0005
10.	0·1019	0·25	5·0	75	3·0–3·5	9·0–10·5	7·8	30	0·1027	+0·0008
11.	0·1223	0·2	5·0	75	3·0–3·5	9·0–10·5	7·8	40	0·1221	−0·0002

No. 1.—Not all out. No. 2.—Slight yellow color with H_2S. No. 3.—Slight yellow with H_2S. No. 4.—Spongy. No. 5.—Not all out. No. 6.—Spongy. No. 10.—Spongy. No. 11.—Slight test with H_2S.

From this series of experiments it may be seen that the method may be made to give fair results if the following conditions are closely adhered to: for a total volume of 75^{cm^3}, the cadmium is precipitated with 0·25 grm. of hydrogen disodic phosphate, 5^{cm^3} of phosphoric acid (sp. gr. = 1·7) added, and the solution electrolyzed with a current of about 8 volts potential. If the normal current density does not exceed 9 amperes, the deposit will be fair, and complete in about 30 minutes.

VI. *In Solutions containing Oxalates.*

Much work was expended upon the oxalate method, but in spite of this, a satisfactory deposit could not be obtained. When ammonium oxalate was present, even in small amounts, the deposit was very spongy: while the use of sodium oxalate alone, when carried down even to the smallest excess possible

*Am. Ch. J., xii, 329 (1890).

to give a soluble double oxalate, gave results much too high. The dissolving of the precipitated oxalates in various reagents furnished no solution to the problem.

The results in the following table will show the scope of the work done:

No.	Cd. tkn. grm.	Am. oxalate. grm.	Pot. oxalate. grm.	Solvent.	Cur't = amp.	N.D$_{100}$ amp.	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0·1491	excess	none	none	3·0	9·0	12	?	0·1558	+0·0067
2.	0·1491	slt. excess	none	"	2·5	7·5	12	30	0·1506	+0·0015
3.	0·1491	2·0	0·5	"	2·0 –2·5	6·0 – 7·5	8	25	0·1531	+0·0040
4.	0·1491	none	0·5	H_2SO_4 15 dps.	2·5	7·5	8	30	0·1476	−0·0015
5.	0·1491	"	8·0	none	2·0	6·0	6·2	20	0·1507	+0·0016
6.	0·1118	4·0	none	"	1·5	4·5	6·1	20	0·1272	+0·0154
7.	?	none	5·0	NH_4OH few cm.	2·0 –3·5	6·0 –10·5	6–8	18	?	?
8.	0·1118	"	5·0	none	1·5	4·5	6·0	15	0·1129	+0·0011
9.	0·1019	"	4·0	"	2·0 –3·0	6·0 – 9·0	8	20	0·0995	−0·0024
10.	0·1019	"	6·0	"	0·5 –1·5	1·5 – 4·5	4–6	35	0·0982	−0·0037
11.	0·1019	"	5·0	"	1·0	3·0	5·5	55	0·1033	+0·0014
12.	0·1019	"	7·0	"	0·5	1·5	4	55	0·1030	+0·0011
13.	0·1223	2·0	8·0	"	0·1 –0·15	0·3 –0·45	4	60	0·1236	+0·0013
14.	0·1223	2·0	8·0	"	0·02–0·10	·06– 0·3	4	76	0·1229	+0·0006
15.	0·1223	KOH 1 grm.	H_2SO_4 dil. 10^{cm}	oxalic acid 5 grm.	3·0	9·0	8	40	0·0876	−0·0347
16.	0·1223	KOH 0·25 grm.	----	oxalic acid 10 grm.	----	----	--	--	----	----
17.	0·1019	----	----	oxalic acid 1 grm.	1-2	3–6	8	35	0·1033	+0·0014
18.	0·1019	----	----	oxalic acid 3·5 grm.	3	9	8	60	0·1018	−0·0001

Of these, numbers 1, 2, 3, 6, 8, 9, 14, 15, 17, and 18 gave very spongy precipitates, while No. 7 was so spongy that it could not be satisfactorily dried, and so was not weighed. In experiments numbered 4, 9, 10, 14, 15, and 18 the cadmium was not all precipitated in the time allowed. In No. 10, also the precipitate was non-adherent. In No. 16, the oxalate was precipitated and was not broken up by the current.

VII. *In Solutions containing Urea, etc.*

Balachowsky* obtained good results by the electrolysis of solutions containing, in addition to cadmium salts, urea and various aldehydes. These solutions were found to offer no difficulties with the rotating cathode, when cadmium sulphate is taken, as may be seen from the following results. The deposits were gray, compact, and quickly dried. The solution was diluted to about 60$^{cm^3}$ or 70$^{cm^3}$, and the best current potential was found to be that given by six storage cells connected in series—approximately 11·8 volts.

* Compt. rend., cxxxi, 385 (1900).

SERIES A.—Urea, 3 grms.

No.	Cd. taken. grm.	Cur't = amp.	$N.D_{100}$. amp.	Time. min.	Cd. found. grm.	Error. grm.
1.	0·1019	0·25–0·5	0·75–1·5	35	0·1018	−0·0001
2.	0·1223	0·2	0·6	35	0·1223	±0·0000
3.	0·1223	0·25–0·5	0·75–1·5	30	0·1230	+0·0007

SERIES B.—Formalin, 2^{cm^3}.

1.	0·1019	0·1 –1·0	0·3 –3·0	30	0·1018	−0·0001
2.	0·1223	0·2 –1·0	0·6 –3·0	30	0·1224	+0·0001
3.	0·1223	0·2 –1·0	0·6 –3·0	30	0·1225	+0·0002

SERIES C.—Acetaldehyde, 2^{cm^3}.

1.	0·1019	0·1 –0·8	0·3 –2·4	35	0·1022	+0·0003
2.	0·1223	0·1 –0·8	0·3 –2·4	30	0·1228	+0·0005
3.	0·1223	0·1 –0·8	0·3 –2·4	30	0·1222	−0·0001

Since the conductivity of the solutions containing urea and the aldehydes is comparatively low, the effect of adding electrolytes was tried. The rate of deposition was very much increased, but the precipitated metal showed such tendency toward sponginess that this procedure is not to be highly recommended. The following were the tests tried:

SERIES A.—Urea, 3 grms.; Time, 20 min.; E.M.F., 7·8 volts; Current read, 0·5 amperes; $N.D_{100}$, 1·5 amperes.

No.	Cd. taken. grm.	Electrolyte.	Cd. found. grm.	Error. grm.	Notes.
1.	0·1019	K_2SO_4, 0·5 grm.	0·1031	+0·0022	spongy.
2.	0·1019	same	0·1031	+0·0022	"
3.	0·1019	H_2SO_4 (1 : 4) 5 drps.	0·1023	+0·0004	good ppt.
4.	0·1019	same as 3	0·1027	+0·0008	slt. spgy
5.	0·1019	H_2SO_4 (1 : 4) 8 drps.	0·1027	+0·0008	" "

SERIES B.—Formaldehyde (formalin), $2·5^{cm}$; Time, 20 min.; E.M.F. 7·9 volts. Current started at 0·5 ampere and rose to 1·0 ampere at the end of the process ($N.D_{100}$ = 1·5–3·0 amperes.) In each case the precipitate was good. Ten drops of dilute sulphuric acid were added to increase the conductivity of the solution.

No.	Cd. taken. grm.	Cd. found. grm.	Error. grm.
1.	0·1019	0·1020	+0·0001
2.	0·1019	0·1019	±0·0000

VIII. *In Solutions containing Formates.*

The use of the solutions containing potassium formate and a slight excess of formic acid has been recommended,* but I

* Warwick, Z. anorg. Ch., i, 285 (1892); Avery and Dales, J. Am. Ch. Soc., xix, 380 (1897).

was unable to adapt this method to the rotating cathode. When potassium formate was present in even the smallest amounts the precipitate was spongy, and non-adherent. From solutions containing formic acid alone, however, the metal is deposited in a satisfactory form, but only after long passage of the current. The following results will show the limit of applicability of the process, experiments numbered 8 and 9 seeming to represent the most desirable conditions:

No.	Cd. tkn. grm.	$KCHO_2$ sat. sol. cm^3.	HOCHO.	Cur't = amp.	$N.D_{100}$. amp.	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0·1019	2	..	1·0 –2·0	3–6	8	17	Not weighed;	
2.	0·1223	0·5	..	0·4	1·2	8	..	ppt.	blistered
3.	0·1223	0·5	..	0·4	1·2	8	..	and	dropped
4.	0·1223	0·5	..	0·4	1·2	8	..	off.	
5.	0·1223	..	15 dps.	0·25–0·8	0·75–2·4	12	25	0·1228	+0·0005
6.	0·1223	..	15 "	0·25–0·8	0·75–2·4	8	25	0·1212	—0·0010
7.	0·1223	..	21 "	0·5 –1·5	1·5 –4·5	12–16	35	0·1202	—0·0021
8.	0·1019	..	1·5$^{cm^3}$	0·5 –1·0	1·5 –3·0	12	60	0·1022	+0·0003
9.	0·1223	..	1·5 "	0·4 –1·0	1·2 –3·0	12	55	0·1218	—0·0005

In the experiments numbered 5, 6 and 7 the cadmium was not all precipitated in the time indicated, as was shown by testing the solution with hydrogen sulphide.

IX. *In Solutions containing Tartrates.*

Solutions containing ammonium tartrate were also tried, but failed to give satisfactory deposits, the deposit in each case being spongy. If the solution contain only tartaric acid, however, in place of its salts, fairly satisfactory results may be obtained, as shown by the following table:

No.	Cd. tkn. grm.	Tartaric acid. grm.	Cur't = amp.	$N.D_{100}$. amp.	E.M.F. vts.	Time. min.	Cd. fd. grm.	Error. grm.
1.	0·1223	3	0·5–1·0	1·5–3·0	8	20	0·1212	—0·0011
2.	0·1223	2	0·5	1·5	8	30	0·1216	—0·0007
3.	0·1223	2	0·5	1·5	8	50	0·1215	—0·0008
4.	0·1019	3	1·5	4·5	11·8	18	0·1022	+0·0003

Tests with hydrogen sulphide showed that the cadmium was not all precipitated in the tests numbered 1, 2 and 3, which were performed at a dilution of 70$^{cm^3}$; experiment 4 was performed at a dilution of 50$^{cm^3}$. It will be noted that, as in the sulphate process, the last traces of cadmium are thrown out of the higher state of dilution only with extreme difficulty.

ART. XXX.—*The Crystallization of Luzonite; and other Crystallographic Studies;* by ALFRED J. MOSES.

1. *The Crystallization of Luzonite.*

THE reddish bronze, fine-grained variety of Cu_3AsS_4 which is found in the copper veins of Mancayan, Luzon Island in the Phillipines, has been generally accepted as dimorphous with enargite, but the minute crystals, "tiny individuals of unrecognizable form,"* observed in the cavities growing from the granular mass have not been measured but rather referred to as "indistinct, uneven, striated crystals not rhombic but monoclinic or even triclinic."†

Recently Mr. Maurice Goodman, senior field assistant in the Bureau of Mines, Manila, collected a number of luzonite specimens showing these crystals in cavities, from which I selected and measured the crystals here described.

Crystals No. 1 and No. 2.—A mass of typical luzonite, free from all visible columnar blackish enargite, showed a number of cavities the walls of which were crystallized; that is, little detached fragments of the walls under the microscope were seen to be facetted by minute crystals which projected very slightly and the faces of which could be traced down until they merged in the bronze-colored mass. They were not implanted on or enclosed in the mass, but distinctly suggested that the mass on solidifying formed little facets such as form on the cooling of a fused mass of pyromorphite. It is curious and probably of genetic significance, that the terminal planes of these crystals are decidedly lighter in color and of less brilliant luster than the side planes, the latter suggesting the dark gray of enargite or stibnite and the former a reddish steel-gray not very different from the tint of the massive luzonite. In more than one instance in which a fracture extended across a crystal into the massive material it was impossible to see any difference in the color or character of the surfaces.

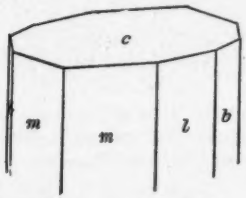
Two little crystals were mounted for measurement. No. 1, shown in fig. 1, was only $\frac{1}{8}$ to $\frac{1}{2}^{mm}$ in any direction, but was attached to a fragment of the mass from which it had developed. Signals were obtained in the two-circle goniometer from seven faces but were a little blurred. Crystal No. 2, shown in fig. 2, was the largest crystal I observed as a cavity wall facet, and its terminal face was approximately a rhomb of $1\frac{1}{2}\times\frac{3}{8}^{mm}$. It also yielded signals from seven faces and a series of signals from a curved triangular surface.

In both crystals the terminal faces were reddish steel-gray and the vertical faces dark gray. Taking the terminal faces

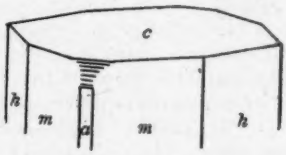
* Weisbach, Tscher. Min. Mitth., 1874, 257.
† Frenzel, ibid., 1877, 303.

as $c = 001$, the consideration of the angles in the vertical zone suggested an orientation for comparison with the common forms of enargite as follows:

1



2



Enargite Form.	Crystal No. 1. Face.	Signal.	Measured ϕ.	Crystal No. 2. Face.	Signal.	Measured ϕ.
$c=001$	1	Fair	----	1	Fair	----
$m=110$	5	Double	48° 57′	2	Double	49° 02′
	6	"	48° 58′	5	Fair	48° 44′
	7	Blurred	48° 30′	-	----	----
$h=120$	-	----	----	3	Faint	31° 44′
$l=130$	2	Fair	20° 22′	-	----	----
	4	Double	19° 17′	-	----	----
$b=010$	3	"	0° 5′	-	----	----
$a=100$	-	----	----	7	Double	89° 46′
hol	-	----	----	curved	Series	90° 0′

The comparison of the averaged angles is:

Enargite ϕ.	Crystal No. 1 ϕ.	Crystal No. 2 ϕ.
$m=48°\ 59'\ 47''$	48° 48′	48° 56′
$h=29°\ 54'\ 13''$	----	31° 44′
$l=20°\ 58'\ 38''$	20° 22′	----
$b=\ 0°$	0° 5′	----
$a=90°$	----	89° 46′

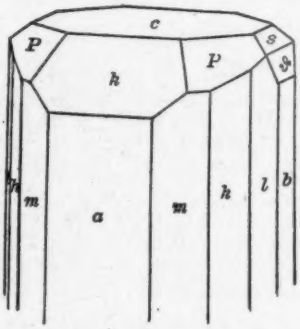
That is, *all* the angles are those of the common forms of enargite within the limits of accuracy that the measurement of minute crystals with rather dull c faces and somewhat striated vertical faces would permit.

Crystals No. 3 and No. 4.—The relatively simple crystals from the cavity walls connect directly with the two other more highly modified crystals here described.

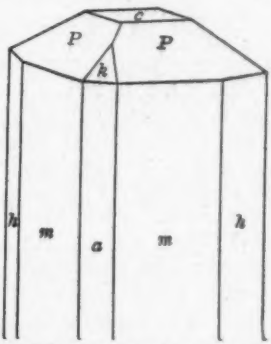
Upon another specimen and so in contact with the massive luzonite as to be, in my opinion, developed from it, were a number of little, bright, highly modified crystals which like Nos. 1 and 2 are much lighter colored on the terminal faces than on the side or prism faces. Crystal No. 3 was the best of these found, and as shown in fig. 3 it proved to include all the forms of Nos. 1 and 2 as well as those of the later described crystal 4. Its size was $\frac{1}{2}\times\frac{1}{8}\times 1^{mm}$ in the directions $\breve{a}$, $\overline{b}$, $\dot{c}$ respectively.

From still another specimen of massive luzonite, but resting upon it rather than growing from it, was a little group of black lustrous crystals, the best of which, crystal No. 4, shown in fig. 4, measured $\frac{3}{16} \times \frac{1}{2} \times \frac{5}{4}$ mm in the directions $\breve{a}$, $\bar{b}$, $\dot{c}$, which,

3



4



while differing from all described enargite crystals in the presence of a pyramid, P = 223, as its most prominent terminal form, connects directly with crystal No. 3 by the fact that this pyramid and all the other forms of the crystal are prominent on crystal 3.

Both crystals were measured in the two-circle goniometer. Crystal No. 3 yielded good to fine signals from twenty-one faces and poorer ones from four others, while crystal No. 4 yielded good signals from twelve faces and poorer from two others. The average results tabulate as follows:

Form.	Crystal.	Number faces.	Measured angles.		Computed enargite angles.	
			ϕ	ρ	ϕ	ρ
c (001)	3	1	----	0°	----	0°
"	4	1	----	0°	----	----
b (010)	3	1*	0°	89° 49½′	0°	90°
a (100)	3	2	90° 04½′	90°	90°	90°
"	4	2*	Approx. 90°	90°	---	----
m (110)	3	4	49° 02′	90°	48° 59′ 47″	90°
"	4	4	48° 57′	90°	----	----
h (120)	3	4	29° 56½′	90°	29° 54′ 13″	90°
"	4	1	30° 03′	90°	----	----
l (130)	3	1	20° 50′	90°	20° 58′ 38″	90°
s (011)	3	1*	0° 1′	39° 40′	0°	39° 36′ 16″
$\breve{s}$ (051	3	2*	0°	76° 18′	0°	76° 24′ 40″
k (101)	3	2	90° 5′	43° 39′	90°	43° 34′ 56″
"	4	2	90°	43° 40½′	---	----
P (223)	3	4	49° 1½′	39° 54′	48° 59′ 47″	40° 3′ 16″
	4	4	48° 59′	39° 56′	----	----

* Poor signals.

The Calculated Angles of Enargite.—The axial elements calculated by Dauber* in 1854 are

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}8711 : 1 : 0{\cdot}8248$$

based upon angles of $mm = 82° 7'$ and $cs = 39° 31'$.

In 1895 Fletcher† calculated new elements

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}8694 : 1 : 0{\cdot}8308$$

based upon angles $mm = 82° 0\frac{1}{2}'$ and $ck = 43° 42'$

This value of mm is the average of so many measurements that it cannot well be questioned and it is not far from the angles here obtained since the mean of twenty ϕ angles of 110 and 223 is $48° 57\frac{1}{2}'$ and Fletcher's $mm = 82° 0\frac{1}{2}'$ yields ϕ of $110 = 48° 59\frac{3}{4}'$.

Fletcher's value for $\dot{c}$, however, considers only the faces $k = 101$ and is the mean of some fourteen values of ck. The new pyramid, P = 223, is represented on crystals Nos. 3 and 4 by eight good faces and the readings especially in crystal 4 are close. The angles ϕ and ρ of 223 in crystal 4 yield $\breve{a} : \bar{b} : \dot{c} = {\cdot}8698 : 1 : {\cdot}8241$, essentially those of Fletcher in the case of $\breve{a}$ but not so near in the case of $\dot{c}$.

I have therefore used in my calculation an intermediate value for $\dot{c}$ of ·8274, which is also an approximate mean between the $\dot{c}$ values of Fletcher and Dauber.

In conclusion, these results show that the crystals which form at the solidification of luzonite and those which form possibly later on luzonite have the angles of enargite. In other words, "luzonite" is not an independent species but merely a variety of enargite.

I base this claim principally on the angles here recorded for the small and relatively simple crystals Nos. 1 and 2, which are types of the cavity-wall crystals so connected with the massive material that it is impossible to doubt that they are the results of its solidification.

Crystal No. 3 I believe to have formed in the same manner but under more favorable conditions, while crystal No. 4 is evidently secondary. The new form P = 223, prominent in both, connects them however.

The observed color difference on the terminal faces and vertical faces of the cavity-wall crystals, and crystal No. 3, probably has genetic significance. The recorded analysis by Winkler is of practically pure material, which makes inadmissible a theory of crystallographic regularity in elimination of impurities. The comparative dullness of the basal plane in Nos. 1 and 2 might suggest a light effect explaining the color,

* Pogg. Ann., lxxiii, 383, 1854.
† Mineralogical Magazine, xi, 73, 1895.

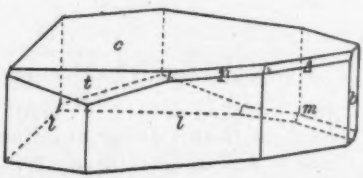
but in crystal No. 3 *c* is bright and the color is still reddish steel-gray. Tarnish does not seem to explain it, as enargite usually tarnishes a blue-black, and finally the possible deposition of a thin layer of dark-colored enargite observed on pyrite associated with Morococho enargite seems not to explain, since the cleavage on No. 3 is also of the dark gray color.

2. *Crystallized Wolframite from Boulder Co., Col.*

Mr. Morris K. Jones, of Boulder, Colorado, sent me a sack of tungsten ore from different lodes in the property of the Great Western Exploration and Reduction Co., situated about twelve miles west of the city of Boulder.

The mineral, which varies in the percentage of manganese in the different lodes, occurs in most of the specimens as the cementing material of a brecciated rock composed chiefly of fine-grained quartz and partially decomposed feldspar. The spaces between the angular rock fragments are filled with the

5



crystalline black ore, the crystals often crossing the crevices. Occasionally the ore thickens to a considerable mass.

On breaking the specimens numerous black brilliant little crystals were found, rarely exceeding $1\frac{1}{2}$ to 2^{mm} in their longest dimension. So far as observed none of the crystals is doubly terminated in the direction of the $\bar{b}$ axis, but all have grown out in that direction from the mass. This and the frequent existence at the visible end of a rectangular face or cleavage $b = 010$ suggests at first examination a simple combination of the three pinacoids. The actual form, however, is that shown in figure 5.

Two crystals, each ending in a b cleavage and essentially alike in habit, were measured. Crystal No. 1 was $\frac{3}{8} \times \frac{1}{8} \times \frac{3}{8}^{mm}$ in the directions $\dot{a}$, $\bar{b}$, $\dot{c}$, and crystal No. 2 a trifle larger.

The forms identified by the measurements were:

Prismatic zone—$l = 210$; $m = 110$; $b = 010$; all yielding good signals from bright decided faces of both crystals.

In addition a signal was obtained from both crystals which closely corresponded to $d = 310$. It was, however, evidently a second element in the striations upon the faces $l = 210$.

The largest face in each crystal was undoubtedly $c = 001$, but these faces were so striated that the series of images gave values for ρ each side of the correct position through four or five degrees, and probably involved various indeterminable domes $h\,0\,l$ and $\bar{h}\,0\,l$.

The remaining forms determined were $t = 102$ well developed; $\Delta = 112$ minute but bright, and a new form, $p = 214$ occurring as a narrow truncation.

The comparison between the measured and computed coördinate angles for l, m, t, Δ and p is:

	Measured.		Calculated.	
Face.	θ	ρ	θ	ρ
l	67° 36¾′	90°	67° 34½′	90°
m	50° 15′	90°	50° 27½′	90°
t	89° 52½′	28° 10½′	90°	28° 3′
Δ	51° 58′	34° 10½′	50° 53½′	34° 29′
p	68° 45′	30° 17′	68° 6′	30° 8½′

Upon a few of the specimens there were small yellow sphalerite crystals and small crystals of scheelite not suitable for measurement.

3. *New Faces on Sylvanite Crystal from Cripple Creek, Col.*

Some three or four years ago Mr. F. C. Hamilton purchased some telluride specimens from a dealer at Cripple Creek, Col., and presented them to Columbia University. Among these was a mass of 3½ oz. in weight which consisted almost entirely of large crystals and crystal bunches some of them 20×5^{mm} in length and breadth. Nearly every one of these was partly coated with a thin layer of chalcedony, but many brilliant faces and cleavages were visible.

There were a few smaller crystals upon the mass which were nearly free from chalcedony; one of these was so symmetrical that it was measured under the impression that it was orthorhombic and possibly a highly modified krennerite. The angles, however, quickly proved its identity with sylvanite.

The dimensions of the crystal were approximately $1 \times 1 \times 2^{mm}$ in the directions $\dot{a}$, $\dot{b}$, $\dot{c}$. For better adjustment the crystal was mounted in the two-circle goniometer with the large $b = (010)$ face parallel to the vertical circle, and centered by this face and the faces of the zone [100 001]. The results were then transformed.

Twenty-six forms were identified, of which twenty have been previously described by Dr. Chas. Palache* on crystals from Cripple Creek; two others, $M = \bar{1}01$ and $p = 112$, are recorded forms not previously noticed on the crystals from this locality

* This Journal, x, 419, 1900.

and four are new domes $H=102$, $T=103$, $l=203$ and $L=\bar{2}03$. The following angles give the proofs for these previously unrecorded and new forms:

	Measured ρ.	Calculated ρ.
$M=\bar{1}01$	34° 35½	34° 18′
$H=102$	19° 19′	19° 12½′
$l=203$	24° 50½′	24° 55′
$T=103$	13° 16½	13° 4½′
$L=\bar{2}03$	24° 13′	24° 27′

For the pyramid $p=112$

Measured angles	$\phi=31°\ 18'$	$\rho=33°\ 30'$
Calculated angles	$\phi=32°\ 0\frac{1}{2}'$	$\rho=33°\ 35\frac{1}{2}'$

The occurring forms and their relative development may be judged by the following tabulation. The forms in the first column are in most cases composed of fine relatively large faces; the largest, however, being the three pinacoids and the three domes $10\bar{2}$, $\bar{1}01$, $\bar{2}03$. All of these domes are new to the locality.

Type.	Faces yielding fine signals.	Faces yielding good signals.	Faces yielding faint signals.
Pinacoids	001, 010, 110	----	----
$hk0$	110, 210	310	----
$0kl$	----	011	----
$h0l$	102, 101	203	103
$\bar{h}0l$	$\bar{1}01$, $\bar{2}03$	----	----
hkl	121, 321	111, 112, 123	141, 323, 521
$\bar{h}kl$	$\bar{1}21$, $\bar{3}21$	$\bar{1}11$, $\bar{1}23$	$\bar{5}21$

4. *Hematite Parting from Franklin Furnace, N. J.*

A mass of ore from Franklin Furnace, N. J., weighing about two pounds, consisted principally of hematite with a very marked rhombohedral parting. With the hematite was calcite also showing a parting (parallel to $01\bar{1}2$) and enclosed within the calcite was a broken crystal about one inch in diameter which consisted of a well-defined crust of hematite with the parting, the red streak, the very feeble manganese and very weak magnetism; and a core of franklinite with different luster, no parting, brown streak, decided manganese reaction and decided magnetism.

For record the nearly cubical parting was measured. The signals are not bright and there is a little calcite between the parting surfaces. Two angles of a fragment yielded respectively 94° 35′, 93° 52′ or an average of 94° 13′. The unit rhombohedron angle of hematite is 94° 0′.

Mr. John Crawford, Jr., made triplicate analyses for me of selected material for total iron and for FeO, the result being:

Fe per cent.	FeO per cent.
67·15	1·97
67·07	1·66
67·22	1·54
67·15 average.	1·72 average.

Deducting the 1·34 Fe equivalent to 1·72 FeO leaves 65·81 Fe present as Fe_2O_3 or 94·00 per cent.

The total analysis becomes:

Insoluble	1·50
CaO calculated to $CaCO_3$	2·85
Fe_2O_3	94·00
FeO	1·72
	100·07

Or recalculating the Fe_2O_3 and FeO to 100 per cent.

Fe_2O_3	98·20 per cent.
FeO	1·80 "

Columbia University, June, 1905.

ART. XXXI.—*The Determination of the Optical Character of Birefracting Minerals;* by FRED. EUGENE WRIGHT.

MINERALS are recognized in the thin section chiefly by their crystallographic properties and by the effect they have on transmitted light. The more important optic features used in their microscopic discrimination are color, pleochroism, refractive index, birefringence, optical orientation, angle between the optic axes (2V),* and optical character. Of these the latter two are determined in convergent polarized light and are well adapted for general application. They furnish exclusive data as to the nature of a given mineral, and can be accomplished by ordinary petrographic microscopes.

The optical character of a mineral, whether positive or negative, depends by definition solely on the value of the bisector of the acute angle between the optic axes; it is, therefore, independent of the crystal system and pertains to all birefracting minerals. The usual methods available for its determination, however, apply in practice only to uniaxial minerals and to those biaxial minerals for which the angle between the optic axes in air (2E) is less than 80°; if 2E exceeds this limit, the traces of the optic axes lie outside of the microscopic field and give rise to uncertainty as to the position of the acute bisectrix, thereby seriously affecting the results. There are several methods, however, which, although not novel in principle, are scarcely recognized in literature, and which practically obviate this difficulty. They are based on phenomena observed in convergent polarized light with nicols crossed and apply equally well to uniaxial and biaxial minerals.

A general consideration of microscopic mineral determination shows conclusively that the optical character of minerals is one of their most useful traits for practical determination since the means employed are simple and of easy application. The following paragraphs aim to present these methods from a working standpoint, the necessary theoretical data appearing in fine print.

The crystal sections of birefracting minerals, from which decisive interference figures can be obtained, are those cut exactly or nearly perpendicular to the bisectrices of the optic axes, to the optic axes, and parallel to the plane of the optic axes. These sections and the methods applicable to them can be discussed for all birefracting substances if uniaxial minerals are treated as a limiting case of biaxial minerals.

* The use of the term optic binormal in place of "optic axes" as proposed by Mr. L. Fletcher in his treatise on The Optical Indicatrix may be an improvement on the original term, but since the distinction implied by the words uniaxial and biaxial is in use in all languages, is convenient and causes no confusion, it is probable that the original designation will remain.

The figures 1–6, used to illustrate the methods, were obtained in part by graphical and in part by mathematical means based on the law of Fresnel, that the planes of polarization for rays traveling in any direction bisect the angles between the planes containing the ray and the two optic axes respectively; in other words, the directions of extinction for any face bisect the angles between the projections of the optic axes on the face.

Plates cut perpendicular to the acute bisectrix.

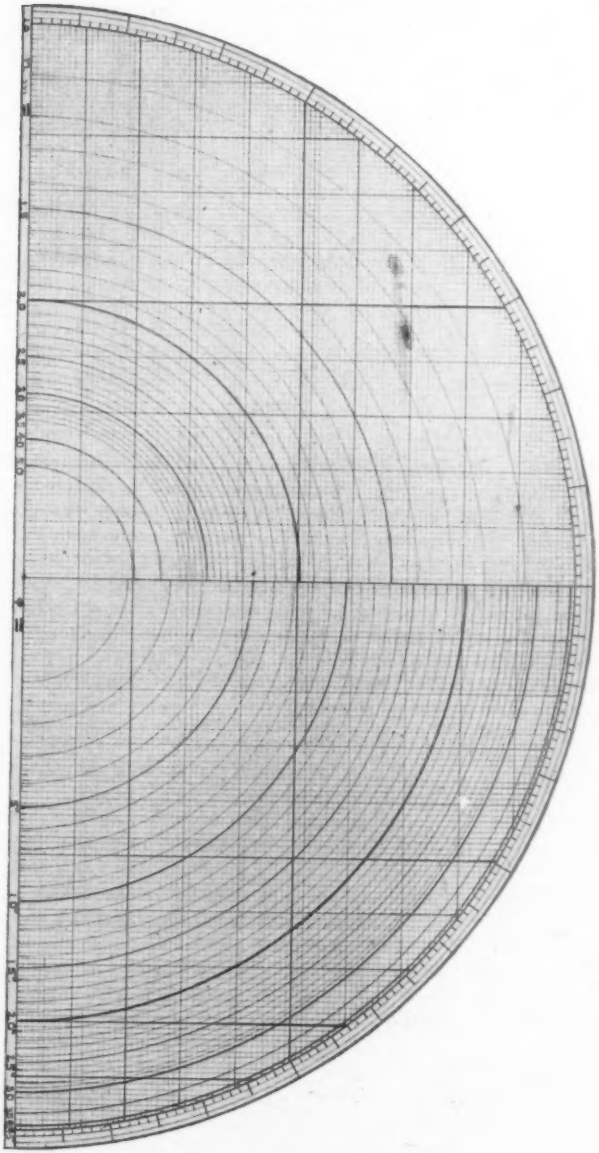
For birefracting minerals in which 2E is less than 80°, the methods ordinarily described in text-books are applicable and satisfactory. Both optic axes appear then in the field, and the optical character can be ascertained in convergent polarized light by observing the change in position of the lemniscatic interference curves in alternate quadrants on the insertion of a quartz wedge or a plate showing the interference-color red of the first order, or a quarter-undulation mica plate. The numerical value of 2E can also be measured on the same section by the Bertrand-Mallard* method described below. For minerals whose 2E is greater than 80°, a method described by Michel Lévy† for determining whether the section is perpendicular to the obtuse or the acute bisectrix can be used to advantage. It consists in observing the angle of revolution of the stage from the position where the black achromatic curves of the interference figure form a cross to that at which they are tangent to a given circle (usually field of the microscope). From this angle 2E can be determined, and from it in turn the true optic axial angle (2V), if the medium index of refraction of the substance be known.

It can be proved both mathematically and graphically that the dark achromatic hyperbolas, which form during the revolution of the stage, pass through the traces of the optic axes and recede from the field along the diagonals of the principal planes of the nicols. Practically, the course of procedure is to find a plate cut perpendicular to the bisectrix, to record the angle of revolution of the stage from the point where the dark hyperbolas intersect to that at which they are tangent to a given circle within the field of vision. From this angle the corresponding axial angle in air can be obtained by using fig. 1a, provided the Mallard constant of the microscope has been previously determined. If the medium refractive index of the mineral is also given, it is possible to convert 2E into 2V by means of fig. 1b.

* E. Bertrand in Mallard, Miner. physique, II, 418. E. Mallard, Sur la mesure de l'angle des axes optiques. Bull. Soc. miner., 1882, page 77 et seq.

† Michel Lévy, Minéraux des Roches, 94–95.

FIG. 1.



1a

1b

Bertrand-Mallard method for measuring the optic axial angle (2E) under the microscope. Mallard has shown that the distance of the trace of an optic axis from the center of the interference figure is proportional to the sine of the angle which the optic axis makes with the axis of the microscope; that, if the distance D be measured by means of a micrometer ocular, the angle E can be figured from the formula

$$\sin E = \frac{D}{K}$$

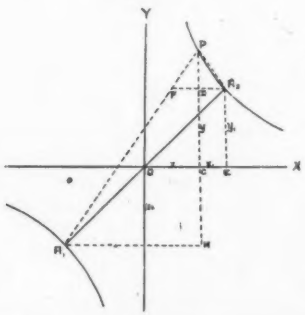
in which K is the constant of the microscope to be determined once for all on a substance whose 2E is known. By drawing a circle of radius K in fig. 1a (once for all), the angle E corresponding to any number of divisions of the micrometer ocular is then the angle in the figure included between its base and the radius passing through the intersection of the arc K with the horizontal line at the distance D from the base line. To convert 2E into 2V use fig. 1a, which was derived from the formula

$$\sin V = \frac{\sin E}{n_m}$$

n_m being the medium refractive index of the substance. The angle 2V is then the angle on the degree circle included between the base line and the horizontal line which passes through the intersection of the radius E and the given refractive index arc.

Michel Lévy method. Michel Lévy has developed a formula from which approximate values of the axial angle 2E can be calculated, provided the index of refraction of the objective lens in which the interference figure is observed be known. As this, however, is not generally the case, a modification of the formula by introducing Mallard's constant in place of the refractive index is better suited to actual practice.

FIG. 2.



In fig. 2* let the plane of the paper represent the section perpendicular to the bisector of the acute optic axial angle and the figure itself the achromatic lines observed in convergent polar-

* Compare Preston, Theory of Light, 3d ed., pp. 400-401.

ized light; A_1A_2, the projection of the optic axes, and P that of any ray in the achromatic hyperbola. Fresnel's law states that the planes of polarization of rays traveling in any direction P are the bisectors of the angles between the planes A_1P and A_2P. For small angles of incidence, the traces of the planes of polarization of the rays will approximately coincide with the bisectors of the angle A_1PA_2. Since P is a point of the achromatic curve, the bisector of the angle A_1PA_2 must be parallel to one of the principal planes of the nicols. The triangle FPA_2 is then isosceles, and the triangles PFD and PDA_2 are similar. Therefore

$$\frac{x_1 - x}{y - y_1} = \frac{x + x_1}{y + y_1}, \text{ or} \tag{1}$$

$$xy = x_1y_1 \tag{2}$$

the equation of an equilateral hyperbola. In order that this curve be tangent to a circle, its tangent must be perpendicular to the radius the equation for which is

$$y = -\frac{1}{\frac{dy}{dx}}x \tag{3}$$

By substituting the value of $\frac{dy}{dx}$ from (2), (3) becomes

$$x = y \tag{4}$$

which shows that the hyperbolic curves are tangent to the circles along the diagonals of the nicols. For these points (2) reads

$$x^2 = x_1y_1 \tag{5}$$

Transforming (5) to polar coördinates, we find

$$\rho^2 = r^2 \sin 2\phi \tag{6}$$

From Mallard's method above, it is evident that

$$r = K \sin E$$
$$\text{and } \rho = K \sin O$$

$$\text{Therefore, } \sin E = \frac{\sin O}{\sqrt{\sin 2\phi}} \tag{7}$$

where sine O is the constant of the circle used and to be determined once for all by the Mallard method. For any given angle of revolution (ϕ) the corresponding E can be found by finding in fig. 1b the intersection of the horizontal line at the distance sine O from the base line with that arc which corresponds to the angle ϕ. 2E can then be reduced to 2V by fig. 1a, if the medium index of refraction be known.

Owing to the width of the achromatic curves, the results attained by this method are only approximate but of sufficient accuracy to be useful in many instances. The angles ϕ can also be figured for sections not exactly perpendicular to the bisectrix; they possess, however, only slight practical value.

The mathematical formula above is only an approximate one, while a graphic method can be applied which is theoretically correct and by which more accurate results can be obtained. The method has been used by Michel Lévy, Viola,* von Fedorow and others in their feldspar studies and is well adapted for general use in the study of optical phenomena.

The lines along which any face will extinguish can be found by passing planes through the normal to the face and the optic axes respectively, and bisecting the traces of these planes on the face. In order to do this readily, a stereographic projection of the optic axes in any desired position should first be made. By a revolution about each of two horizontal axes in the principal planes in the nicols, any face normal can be brought to coincide with the pole of the projection and the face with that of the paper. The bisectors of the angles between the straight lines drawn through the pole of the projection and the optic axes in their new positions are then the desired directions. The achromatic black hyperbolas of the interference figure correspond to those face-normals whose extinction lines are parallel to the axes of revolution of the projection. In the projection the achromatic lines, however, do not appear as they do when observed under the microscope, for its interference figure can be considered with slight error as an orthographic projection of the rays on a sphere, as shown by Mallard's formula above. The curves of the stereographic projection must therefore be replotted by making the polar distance sine E instead of tan $\frac{E}{2}$ as it is in the stereographic projection. The general aspect of the curves is not changed by this transformation. The graphic method has been applied to the methods below with satisfactory results. (Figs. 4 and 6.)

The interference figure from the section perpendicular to the obtuse bisectrix differs from the above only in the wider optic axial angle, which can be measured by the same methods.

Plate perpendicular to an optic axis.

The interference figure obtained from this plate consists ordinarily of a black achromatic bar which revolves in a direction opposite to that of the stage. In general the bar is a straight line only when it is parallel to the planes of polarization of the nicols; in the intermediate positions it is more or less convex, depending on the angle between the optic axes. If 2E, however is equal to 90°, the curve is a straight line in all positions for the usual microscopic field of vision.

* Michel Lévy, Sur la determination des feldspaths, 1894, pp. 15–20. C. Viola, Zeitschr. für Kryst., xxx, 232, xxxi, 484, xxxii, 305. E. von Fedorow, Zeitschr. für Kryst., xxxi, 579, xxxii, 246.

FIG 3.

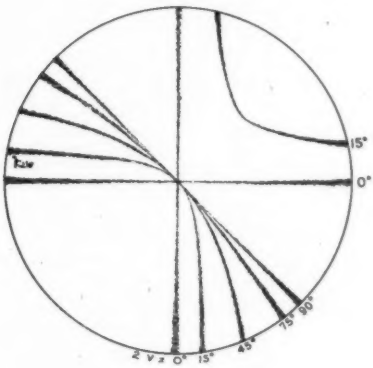
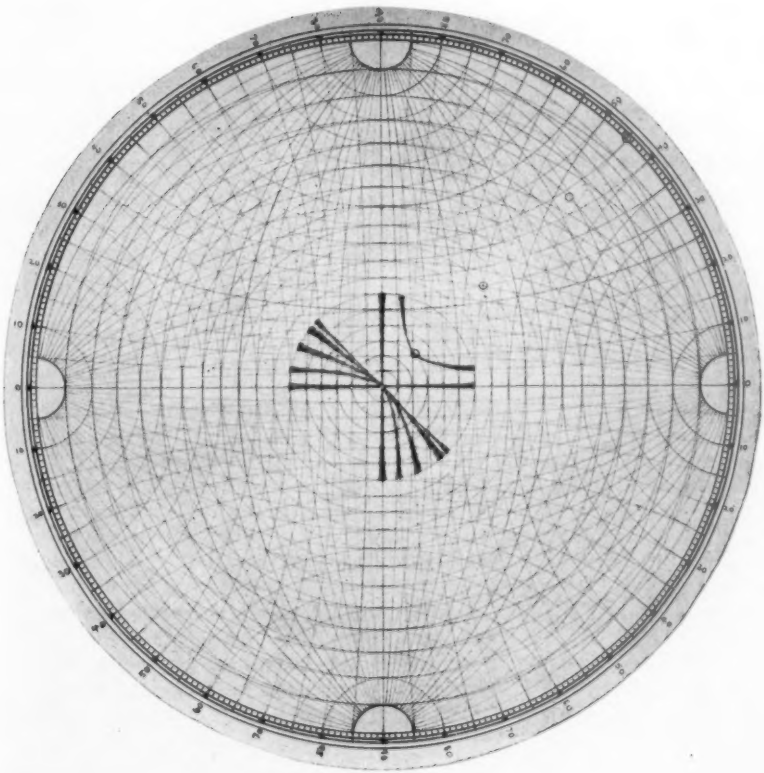


FIG. 4.

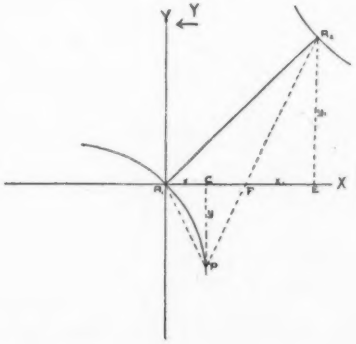


An examination of the curves for the several optic axial angles, figs. 3 and 4, indicates clearly that the convex side of the bar in the diagonal position points toward the acute bisectrix. The determination of the optical character is effected then most readily by means of the red of the first order plate. If the achromatic bar of the interference figure be placed in the position of fig. 3 with the convex side of the hyperbola pointing to the northeast and the arrow of the plate (direction of least ellipsoidal axis) also in the same direction, the convex side of the curve will show a blue interference color if the mineral is optically negative; the blue spot will be on the concave side of the curve if it is optically positive.

This method can always be applied if the convexity of the curve can be discerned. In certain plagioclase feldspars, the limiting case of $2V = 90°$ is encountered occasionally and there the bar is in fact a straight line. For most of the feldspars, however, the curvature is sufficiently marked to enable a determination of their optical character. The result can be checked by extinction angles of the section and adjacent twinning lamellæ after the method of Michel Lévy.

The approximate formula for the achromatic curves from this plate can be derived from a discussion of fig. 5, which is based on assumptions similar to those obtaining for the curves of the plate perpendicular to the acute bisectrix.

FIG. 5.



The similar triangles A_1PC and A_2FE give at once the relations

$$\frac{x}{y} = \frac{x_1 - 2x}{y_1} \tag{1}$$

$$xy_1 = yx_1 - 2xy \tag{2}$$

the equation of an equilateral hyperbola passing through the zero coördinate point with asymptotes parallel to the X and Y axes. For the special case under consideration where $x_1 = y_1$, the formula becomes

$$y = \frac{1}{\frac{1}{x} - \frac{2}{x_1}} \qquad (3)$$

From (3) the curves of fig. 3 were plotted in gnomonic projection.

For $x_1 = \infty$, equation 3 becomes

$$x = y$$

the equation of a straight line passing through the zero point at an angle of 45° with the coördinate axes. If the formula of Mallard were exact, x_1 could not assume a value greater than 1 (sine 90°); since it is approximately correct only for small angles, the above remark does not obtain. The gnomonic projection was, therefore used in fig. 3 instead of the orthographic.

In such limiting cases the graphic method gives more satisfactory results and is in general better suited to the study of optical phenomena. In fig. 4, the stereographic plat with curves for optic axial angles 0°, 15°, 45°, 75°, and 90° is given. Their course in the vicinity of the pole of the projection only is represented since it corresponds to that portion which is seen under the microscope.

*Plate parallel to the plane of the optic axes.**

In the uniaxial minerals this plate corresponds to any section in the prism-zone.

The interference figure from the section can be recognized by the fact that in the position of darkness the entire field is practically dark and that a small revolution of the stage (5°) will cause the faint hyperbola to recede entirely from the field of vision. In the diagonal position the colored interference curves have the form of hyperbolas.

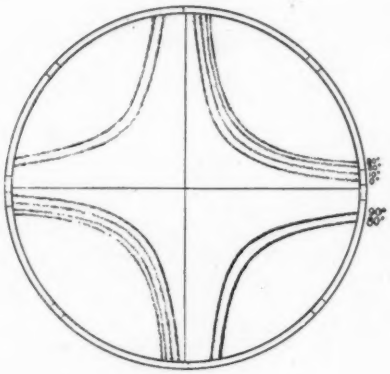
Since ordinary approximate methods of calculation do not apply to this section, the graphic method with the stereographic projection plat as base was adopted. The result, as depicted by the curves of fig. 6, shows that the recession of the dark achromatic lines for the optic axial angles $2V = 0°$, 10°, 80°, and 90° after a revolution of 1° of the stage is very marked, and that, except in the limiting case of $2V = 90°$, the dark hyperbolas pass out of the field most slowly in the direction of the acute bisectrix. For $2V = 90°$ the hyperbolas in all quadrants recede from the center with equal rapidity. In fig. 6

* Compare F. E. Wright, this Journal, xvii, 387–391.

the lines between the outer and inner circles represent the actual position of the bisectrices and optic axes under the conditions stated.

Owing to the fact that for this section the angles of extinction are very low for all rays whose angle of incidence is small, the intensity of the rays adjacent to those of the achromatic curve is also low, since it varies with the square of the sine of

FIG. 6.



the angle ρ between the planes of polarization of the nicols and that of the section according to the formula

$$I = \sin^2 2\rho \sin^2 \frac{\pi}{\lambda}(o-e)$$

The black curves are therefore indistinct and require careful scrutiny to be observed at all.

The colored hyperbolic interference curves which appear in the interference figure most sharply in the diagonal position of the section can also be used to locate the direction of the acute bisectrix. It can be proved in several different ways that the acute bisectrix is generally direction of less birefringence than the obtuse bisectrix. The birefringence of any section can be figured approximately by the formula

$$\gamma' - a' = (\gamma - a) \sin \theta_1 \sin \theta_2$$

where γ' and a' denote the maximum and minimum refractive indices of the given section, γ and a those of the mineral, θ_1 and θ_2 the angles between the normal to the section and the

optic axes respectively. The formula indicates clearly that, except in the limiting case of $2V=90°$, the birefringence for sections in the alternate quadrants containing the acute bisectrix is less than that for corresponding sections in the two remaining quadrants. The rule resulting from this fact is that the interference colors for points in the quadrants containing the acute bisectrix are lower than those for corresponding points in the direction of the obtuse bisectrix.

After the direction of the acute bisectrix has been found by one of the above methods, its value (c or a) can be readily ascertained by ordinary methods either in parallel or convergent polarized light.

Summary.

In the practical determination of minerals under the microscope advantage is taken chiefly of those properties which are definite in character and which can be readily ascertained. Of these the optical character is one of the most useful since it applies to all birefracting minerals and can be determined in convergent polarized light on plates cut along one of several different directions:

1. On plates perpendicular to the acute bisectrix, by observing the direction of movement of the curves of the interference figure on the insertion of a quartz wedge, mica plate, or plate showing the interference color red of the first order. If the loci of the optic axes lie outside of the field, determine whether the plate is perpendicular to the obtuse or acute bisectrix by measuring the optic axial angle in air by the modification of the Michel Lévy method described on page 288. The reduction of the observed optic axial angle to that in the crystal can be accomplished only when the medium refractive index of the substance is known and then easily by fig. 1.

2. On a plate perpendicular to an optic axis by noting that, when the black achromatic bar lies in a position diagonal to that of the principal planes of the nicols, its convex side points toward the acute bisectrix and that on the insertion of a plate showing the interference color red of the first order, the convex side will be colored blue if the arrow (n) of the inserted plate lies in the plane of the optic axes and the mineral is optically negative; if the blue spot lies on the concave side of the bar and the arrow of the plate still lies in the plane of the optic axes, the mineral is optically positive. This method is applicable whenever the curvature of the achromatic bar can be observed. The section is moreover easy to find because in parallel polarized light with nicols crossed it remains nearly dark for all positions of the stage.

3. On a plate parallel to the plane of the optic axes the direction of the acute bisectrix can be located by two different methods:

a. Revolve mineral from the position of darkness through a small angle and note that the direction in which the faint dark hyperbolas recede from the field is that of the acute bisectrix. *b.* In the diagonal position of the interference figure observe the interference colors of corresponding points in adjacent quadrants and note that the points in the direction of the acute bisectrix show the lower interference colors. In both cases the value of the acute bisectrix (c or a) can be determined either in convergent or parallel polarized light by the usual methods and thus the optical character of the mineral be ascertained.

U. S. Geological Survey, Washington.

Art. XXXII.—*On Groups of Efficient Nuclei in Dust-Free Air;* by C. Barus.

1. *Dust-free Air.*—By this term I refer to atmospheric air filtered with extreme slowness (through large wide filter of packed cotton) and thereafter left without interference for two or more hours. Such air shows a high fog limit. In the fog chamber used the coronal condensation begins at a pressure difference of about $\delta p = 26$ cm., rain-like condensation at $\delta p = 21$ cm.

In the present experiments all tests are made at $\delta p = 41{\cdot}5$ cm., at a pressure difference therefore much above the fog limit, and probably approaching the condensing power of the apparatus. The number of nuclei computed from the coronas observed is an approximation merely, as the constants needed for the very large range of variation in question are not available. Nevertheless, if the same δp is used throughout, the nucleations obtained are immediately comparable. With these reservations* the number of nuclei found in the dust-free air and at the δp in question is about 380×10^3 to 400×10^3 per cm^3. It is obvious, moreover, that these nuclei are excessively small, much smaller than ions, smaller even than those which would respond to smaller exhaustions, exceeding $\delta p = 26$ cm.

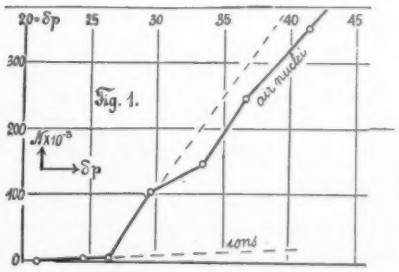


Fig. 1.

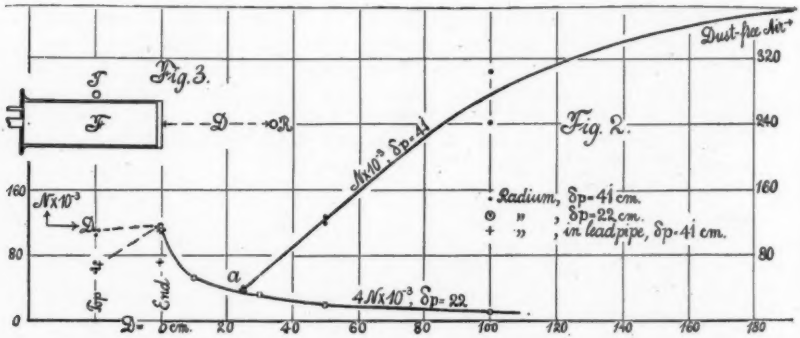
In figure 1 I have given an example of these relations. Between $\delta p = 21$ and 26 (for this apparatus) condensation probably takes place largely on ions, above that on the nuclei of dust-free air. The upper dotted line shows the limit of value found, the latter being variable because (as will appear more clearly below) the ionization of atmospheric air is essentially variable. Though relatively small in number, the ions from their larger size probably capture much of the moisture.

2. *Effect of Radium.*—Now let the fog-chamber (fig. 3) be subjected to the radiations from weak radium (10,000 ×, 10 mg.) contained in a thin hermetically sealed aluminum tube. As the walls of the fog-chamber are ·3 cm. thick and

* The nuclei are supposed to be removed by exhaustion, faster than they can be restored, either by radiation or by the molecular mechanism.

the end (bottom) toward the tube nearly 1 cm. thick, γ-rays only will penetrate into the inside apart from the secondary radiation there produced. In figure 3 F is the cylindrical fog-chamber, R the radium tube at an axial distance D from the nearer end. In addition to this the radium was also tested at T (top) in the figure, where it is nearest the body of dust-free air under experiment.

Within the fog-chamber the coronas are everywhere normal and of the same size, in spite of the axial length of 45 cm. available. This is a singular result when contrasted with the marked positional effect observed for the case of radium placed at the different distances D outside of the chamber. The data investigated are shown in the curve (fig. 2), where the abscissas are the distances D and the ordinates the number of *efficient* nuclei per cm^3.



It follows from the graph that as the radium is brought in an axial direction from ∞ to the end of the fog-chamber, the number of efficient nuclei in the dust-free air contained is gradually but enormously reduced to a minimum for $D = 25$ cm. (about), after which the number again increases to the maximum at $D = 0$. Curiously enough, if the radium is further approached to the body of the air by being placed at T, the number of nuclei does not increase; in some observations it even diminishes.

If the radium is enclosed in a long thick lead tube (60 cm. long, walls ·5 cm. thick), the nucleation is but moderately reduced (see fig. 2, crosses), showing that γ-rays are in question.

4. *Cause of the minimum.*—This is easily explained since the ions are relatively large bodies and relatively few in number as compared with the nuclei of dust-free air for the same δp. Hence the ions virtually capture the moisture more and more fully as their number, with diminishing distance D, becomes greater. At $D = 25$ cm. probably the whole of the

moisture is condensed on ions, and as their number increases as D vanishes, the minimum in question results.

In fact it was shown elsewhere, that below the fog-limit of air, the nucleation observed and due purely to radium at different distances D, is for example ($\delta p = 22$)

$D =$	0	10	30	50	100	
$N \times 10^{-3}$	120	50	32	20	12	etc.

agreeing in character as far as may be expected with the data here in question. These data multiplied by 4, i. e., $4\,n \times 10^{-3}$, are also given in figure 2 for comparison. Hence the ions caught at $\delta p = 41{\cdot}5$ are about four times more numerous than at $\delta p = 22$, and correspondingly smaller. They are, therefore, markedly graded, but nevertheless, as a group, throughout much smaller than the nuclei of dust-free air so long as the radiant field is appreciable. Whether the latter are agglomerated under the influence of radiation to make the ions (as would seem more probable), or whether the ions are made from the molecules themselves so that the ions and the nuclei of dust-free air are present together, is a question beyond the scope of the method. While the number of nuclei continually grows smaller, with diminishing D, the efficient or capturing nuclei may nevertheless increase again below a certain D, seeing that the nuclei in dust-free air are enormously in excess, only a few of which are caught even in the absence of radium.

4. *Cause of the maximum.*—It is more difficult to account for the result that the same nucleation is observed wherever the radium touches the elongated fog-chamber. In other words, radium at the end of the chamber produces at least the same nucleation as when at the top, although the distances from the center of mass of the glass are as 3 to 1. The same kind of explanation already given in § 3 may possibly hold. The radium tube when placed on the top (T in figure 3) and in contact with thinner glass, may act with sufficient intensity to admit of the formation in turn of a group of nuclei larger than ions. This is what actually occurs in the case of X-rays. But it is more probably connected with the uniform distribution of nuclei within the chamber (§ 1) and in some way referable to secondary radiation evoked within the chamber. Secondary radiators added on the outside are quite without effect.

5. *General Conclusion.*—The occurrence of a continuous succession of groups or gradations of nuclei in the curve of figure 2, each of which groups constitutes a condition of chemical equilibrium for the given radiating environment, is suggestive. In the first place, it may be recalled that the nuclei of dust-free air are an essential part of this body as much as the molecules themselves. Such nuclei if withdrawn by precipi-

tation are at once restored. Again air left without interference for days shows a maximum of this nucleation for the given conditions of exhaustion when all foreign nucleation must have vanished. Indeed the molecules themselves may be treated as a continuous part of the nucleation in question, the frequency of occurrence being a maximum for the molecular dimensions.

Furthermore in the presence of radium the character of the phenomenon is the same, only the nuclei are larger. If withdrawn by precipitation, they are at once restored. They are an essential part of the air in the new environment.

It is natural to compare the particular nuclear status introduced in the latter case by a particular kind of radiation (γ rays), with the former case of dust-free air in the absence of recognized radiation. In other words, quite apart from the details of the mechanism, chemical agglomeration might be considered referable to an unknown radiant field, but be otherwise essentially alike in kind to the much coarser nucleations observed in the known radiant fields of the above experiments. But the effect of radium, however distant, is always virtually an increase of the size of the air nuclei and a decrease of their number. Hence if we were to fancy that the nucleation (not the ions, of course) of non-energized dust-free air responds to its own radiant environment, this radiation would have to be special in kind.

Returning to the case of the gamma rays, fig. 2, (or of the X-rays coming from a distance,) let me recall that the effective radiation within the fog chamber is everywhere the same and the same in all directions. Hence whether the radiation be corpuscular or (in other cases) undulatory, the interior is nothing less than an ideal Lesage medium; and there must therefore be a tendency at least to agglomerate the colloidal nuclei of dust-free air into fleeting nuclei or ions, so long as the radiation lasts. When it ceases the ions are free to fall apart, so far as external influence goes, as they actually do. Furthermore since the pressure so obtained would increase with the number of corpuscles per cubic cm. and with the square of their velocity, it is conceivable that with increasing electrification this pressure would become strong enough to bring about permanent union of the aggregates, corresponding to the observed continuous transition of the ions into persistent nuclei, produced by the X-rays. Again a different nucleus would presumably correspond to the bombardment of the negative corpuscles as compared with the residual positive quantities. Finally, if any physical or chemical process like combustion or ignition or electric charge, or the case of phosphorus, etc. is accompanied by intense ionization, one would for the same reason anticipate the presence of nuclei in such a field.

Brown University, Providence.

ART. XXXIII.—*Studies in the Cyperaceæ;* by THEO. HOLM.

XXIV. New or little known *Carices* from Northwest America. (With 18 figures, drawn from nature by the author.)

WITH the object of preparing a treatise of the genus *Carex* as represented in the northwestern part of this continent the writer has examined several very extensive collections, containing a vast number of specimens, among which some few have been observed as imperfectly understood or as hitherto undescribed. Inasmuch as the treatment of the genus in a subsequent paper will be from a geographical point of view, we prefer to publish the diagnoses of the new species separately with some remarks upon their affinities.

These species are:

Carex limnæa sp. n. (figs. 1–3).

Rhizome vertical with ascending shoots and light brown, fibrillose leaf-sheaths; leaves a little shorter than the culm, narrow, but flat, glaucous, scabrous along the margins; culm about 60^{cm} in height, erect or slightly curved above, very slender, triangular, scabrous, phyllopodic; spikes 3 to 5, but mostly 4, the terminal staminate or, sometimes, androgynous, the lateral pistillate, the uppermost contiguous, the lowest remote, sessile to shortly peduncled, erect, not very dense-flowered, cylindric, about 2^{cm} in length, subtended by sheathless, foliaceous bracts, the lowest one often exceeding the inflorescence; scale of staminate spike lanceolate, light purplish-brown with green midvein; scale of pistillate spike oblong, obtuse, black with hyaline apex and greenish midvein, shorter than the perigynium; perigynium stipitate, slightly spreading, narrowly elliptical, granular, plano-convex, prominently many-nerved on the outer (convex) face, three-nerved on the inner, pale green with a black, entire and very distinct beak; stigmata 2, style long and exserted.

Oregon: Crater Lake National Park, Cathedral spring, collected by Mr. F. V. Coville, September, 1902 (No. 1456); Fourmile Lake, Klamath County, in meadows, and between Diamond and Crescent Lakes, Cascade Mountains.

The graceful habit of this species reminds us more of *C. rhomboidea* than of *C. vulgaris*, but when we, nevertheless, prefer to place it nearer *C. vulgaris* it is on account of the structure of the perigynium, narrowly elliptical and prominently many-nerved.

Carex brachypoda sp. n. (figs. 4–6).

Rhizome short with ascending shoots and persisting, dark brown leaf-sheaths; leaves shorter than the culm, relatively broad (about 5^{mm}) and flat, deep green, scabrous along the margins and lower face, glabrous above; culm about 35^{cm} in height, erect, stiff, triangular, scabrous, phyllopodic; spikes 3 to 4, mostly 4, the terminal staminate, the lateral pistillate, somewhat remote, sessile or the lowest one short-peduncled, erect, dense-flowered, cylindrical, from 1 to 2^{cm} in length, subtended by sheathless bracts with narrow blades much shorter than the inflorescence; scale of staminate spike lanceolate, reddish brown with pale midvein; scale of pistillate spike ovate, obtuse, black with green, not excurrent midvein, a little shorter than the perigynium; perigynium minutely stipitate, erect, almost orbicular, granular and denticulate along the margins above, compressed, nerveless, pale green, the minute beak dark purple with the orifice entire, papillose; stigmata 2.

Oregon: Crater Lake National Park, Cathedral spring, collected by Mr. F. V. Coville, September, 1902 (No. 1455).

The affinity of this species is with *C. gymnoclada*, but it differs from this by the perigynium for instance, which is more roundish, denticulate and very shortly beaked.

Carex pachystoma sp. n. (figs. 7–8).

Rhizome cæspitose with strong roots and persisting, reddish leaf-sheaths; leaves almost as long as the culm, quite broad and flat (0·5^{cm}), glabrous, light green; culm from 30 to 56^{cm} in height, erect, somewhat slender, triangular, scabrous, phyllopodic; spikes 4 to 6, the terminal and uppermost lateral staminate, the others pistillate, remote or the uppermost contiguous, all, especially the lower ones, slenderly peduncled, erect or spreading, dense-flowered except at the base, from 3 to 5^{cm} in length, subtended by sheathless, leafy bracts about as long as the inflorescence or a little longer; scale of staminate spike lanceolate, obtuse, purplish brown with green midvein; scale of pistillate spike lanceolate, mucronate, deep purple with broad, green midvein, narrower, but longer than the perigynium; perigynium sessile, slightly spreading, elliptical, granular, compressed, nerveless, green or purplish-spotted above, the beak short and thick, sparingly denticulate, the orifice very narrow, slightly emarginate on outer face; stigmata 2.

Oregon: Crater Lake National Park, Anna Creek Canyon, near the falls (No. 1362) and near Odell Lake, Klamath County (No. 520), collected by Messrs. Applegate and Coville.

Washington: Springy places, northern slope of Mt. Adams, and Falcon Valley, W. Klickitat County (No. 2959), by Mr. W. Suksdorf.

The species may be placed between *C. variabilis* and *C. lenticularis*, although it shows some approach to *C. acutina*, though merely in respect to its habit. We have examined a number of specimens and are unable to refer the plant to either of those mentioned above.

Carex Nebraskensis Dew.

Habitually and in several other respects this species seems inseparable from the *Microrhynchæ*, but we have placed it* as one of the most evolute types of these on account of the bidentate beak of the perigynium. It is excellently described by Boott,† and well marked by the strong stolons covered by brown scale-like leaves, which are never shining, by the pale, glaucous leaves and especially by the perigynium with its prominent ribs and bidentate beak. In the extensive collection of Mr. Suksdorf we found several specimens, which were somewhat like this species, but a careful examination of the spikes convinced us that these could not safely be referred to the species, nor ought they to be considered as simply varieties, hence we prefer to describe them as two distinct species: *C. eurycarpa* and *C. oxycarpa*.

Carex eurycarpa sp. n. (figs. 9–10).

Rhizome stoloniferous with persisting, brown leaf-sheaths and strong roots; leaves half as long as the culm, narrow (3^{mm}), carinate, light green, scabrous along the keel and margins; culm 60^{cm} in height, erect, slender but somewhat stiff, scabrous, triangular, phyllopodic; spikes 3 to 5, mostly 5, the terminal and, sometimes, the uppermost lateral staminate, the others purely pistillate, all remote; the pistillate short-peduncled, erect, dense-flowered except towards the base, until 5^{cm} in length, cylindric, but relatively thin, subtended by narrow, sheathless bracts, about as long as the inflorescence; scale of staminate spike oblong, obtuse, light brown with pale midvein and narrow, hyaline margins; scale of pistillate spike lanceolate, acute, blackish with pale, not excurrent, midvein, narrower, but about as long as the perigynium; perigynium sessile or nearly so, erect, roundish, granular, slightly planoconvex, prominently many-nerved on both faces, brownish, the beak short, emarginate; stigmata 2.

Washington: W. Klickitat County, Falcon Valley, collected by Mr. W. Suksdorf, June, 1886 (Nos. 1284 and 2962).

Carex oxycarpa sp. n. (figs. 11–12).

Rhizome stoloniferous with strong roots and persisting, brown leaf-sheaths; leaves a little shorter than the culm, nar-

* The author: Greges Caricum. (This Journal, vol. xvi, p. 457, 1903.)
† Ill. gen. Carex, vol. iv, p. 175 and plate 592.

row (4mm), carinate, light green, scabrous; culm about 75cm in height, erect, slender, but somewhat stiff, triangular, scabrous, phyllopodic; spikes 4 to 5, the terminal staminate, long-peduncled, the lateral pistillate, contiguous, seldom remote, short-peduncled, erect, dense-flowered, cylindric, from 2 to 4cm in length, subtended by sheathless, narrow, foliaceous bracts, the lowest one exceeding the inflorescence; scale of staminate spike oblong, obtuse, light reddish-brown with pale midvein; scale of pistillate spike lanceolate, acute, blackish with pale, not excurrent midvein, narrower, but about as long as the perigynium; perigynium sessile, broadly elliptical, granular, compressed, prominently 3-nerved, brownish, prominently denticulate along the margins from near the base to the short, emarginate beak; stigmata 2.

Washington: W. Klickitat County, meadows near the Columbia, collected by Mr. W. Suksdorf, June, 1885 (No. 816).

Of these *C. eurycarpa* is a very slender plant and much more so than any of the numerous specimens of *C. Nebraskensis*, which we have studied. The broad perigynium with the beak merely emarginate constitutes, also, a good distinction. In the other, *C. oxycarpa*, we have, also, a plant of slender habit, but the spikes are relatively heavy, and the perigynium is here merely 3-nerved and with the margins quite prominently denticulate from the base to the emarginate beak.

The affinity of these two species is unquestionably with *C. Nebraskensis* Dew., next to which they should be placed in the system.

Carex campylocarpa sp. n. (figs. 13–15).

Rhizome with short stolons and purplish, persisting leaf-sheaths; leaves shorter than the culm, narrow, but flat, scabrous along the margins and on the lower face; culm about 40cm in height, erect, stiff, triangular, scabrous, phyllopodic; spikes 3 to 4, mostly 3, the terminal staminate, the lateral pistillate; remote, sessile or nearly so, erect, dense-flowered, short cylindric to ovoid, from ½ to 1cm in length, subtended by sheathless, foliaceous bracts, shorter than the inflorescence; scale of staminate spike lanceolate, obtuse, purplish brown with pale midvein; scale of pistillate spike ovate, obtuse, blackish with the midvein faintly visible and the margins narrow, hyaline, much shorter than the perigynium; perigynium shortly stipitate, spreading, elliptical-oblong, granular and prominently denticulate along the upper margins, turgid, nerveless, pale green with purplish spots and streaks, the beak quite prominent, excurved, the orifice entire; stigmata 2, style not exserted.

Oregon: Crater Lake National Park, Cathedral spring, collected by Mr. F. V. Coville, September, 1902 (No. 1457).

The systematic position of this species seems naturally to be among the *Microrhynchæ*, but as a deviating type on account of the excurved beak of the perigynium, and if it were not for the distinct marginal denticulation of the perigynium and its slender shape the species would resemble *C. scopulorum* to some extent. A perigynium of this kind is somewhat unusual within the representatives of the grex, but is, as we remember, very characteristic of the *Spirostachyæ;* in these, however, the beak is generally bifid and more distinctly differentiated from the body. The species may be placed next to *C. scopulorum.*

Carex cryptochlæna sp. n. (fig. 16).

Rhizome cæspitose with purplish, persisting leaf-sheaths; leaves about half as long as the culm, broad (about 1^{mm}) and flat, glabrous except along the margins; culm from 70 to 90^{cm} in height, erect and stiff, triangular, scabrous along the edges, phyllopodic; spikes from 4 to 7, the terminal and frequently the uppermost lateral staminate, the others pistillate or androgynous, contiguous or the lower ones remote, sessile or short-peduncled, erect or spreading, seldom nodding, dense-flowered, subtended by sheathless, foliaceous, broad bracts of which the lower ones exceed the inflorescence; scale of staminate spike elliptical-oblong, acute, light reddish-brown with pale midvein; scale of pistillate spike lanceolate, sharply pointed, deep purplish with broad, greenish midvein, exceeding the perigynium; perigynium almost sessile, erect, broadly elliptic to roundish, nerveless, pale green, granular, sparingly denticulate near the minute, entire beak; stigmata 2.

Alaska: Kussiloff, on sands with Elymus, collected by Dr. Walter H. Evans, July, 1898 (No. 618), and Seldovia near mouth of Cook inlet by Prof. C. V. Piper, August, 1904 (Nos. 4818 and 4819).

This species is somewhat remarkable on account of its resemblance to *Carex cryptocarpa*, so far as concerns the structure of the spikes, the deep-purplish, lanceolate scales and the broad pale-green perigynia. But it shows, on the other hand, a striking contrast to this species, *C. cryptocarpa*, not only by the almost sessile and mostly erect pistillate spikes, but also by its very broad leaves, the basal and the bracts. Habitually the species does not resemble *C. cryptocarpa*, but, to some extent, Drejer's *C. hæmatolepis* or certain very robust forms of *C. salina;* it appears, however, to be distinct from these, and as a type intermediate between the true *Salinæ* and *C. cryptocarpa* Mey.

Carex luzulæfolia W. Boott var. *strobilantha* nob. (fig. 18).

Taller and more robust than the typical plant; the spikes thick and very compact-flowered; scales of staminate and pistil-

late spikes mostly mucronate; perigynium glabrous throughout, faintly nerved on the inner face, nearly sessile, roundish in outline and terminated by a very distinct, bidentate beak.

California: Above Donner Pass in Placer County, in a subalpine meadow, where snow-drifts lie late, and usually near granite rocks, collected by Mr. A. A. Heller, August, 1903 (No. 7187).

In the specimens of this new variety the rhizome is densely matted with ascending shoots and covered by dark, brownish fibers from the old leaf-sheaths. The leaves are very broad, but much shorter than the culms. The heavy, deep-brown spikes remind of small cones, hence the name "*strobilantha*," and there is quite a variation in respect to their number, position and the distribution of the sexes. We noticed the following instances in 26 specimens:

2	staminate	and	3	pistillate	spikes	in 14	specimens.
1	"	"	3	"	"	5	"
2	"	"	4	"	"	2	"
1	"	"	4	"	"	2	"
2	"	"	2	"	"	1	"
3	"	"	3	"	"	1	"
3	"	"	1	androgynous	"	1	"

In some specimens the pistillate spikes were borne on very long peduncles overtopping the terminal, and several of these were observed to be more or less decompound.—The structure of the perigynium is very characteristic and differs essentially from that of the typical plant, which, as described by W. Boott,* is: "oval to lanceolate," "slenderly nerved, slightly serrate on the upper margins, longer and broader than the scale." The accompanying figures of the perigynia show the distinction very plainly, a distinction, however, which appears to the writer as merely varietal.

Brookland, D. C., May, 1905.

* S. Watson: Botany of California, vol. 2, p. 250, 1880.

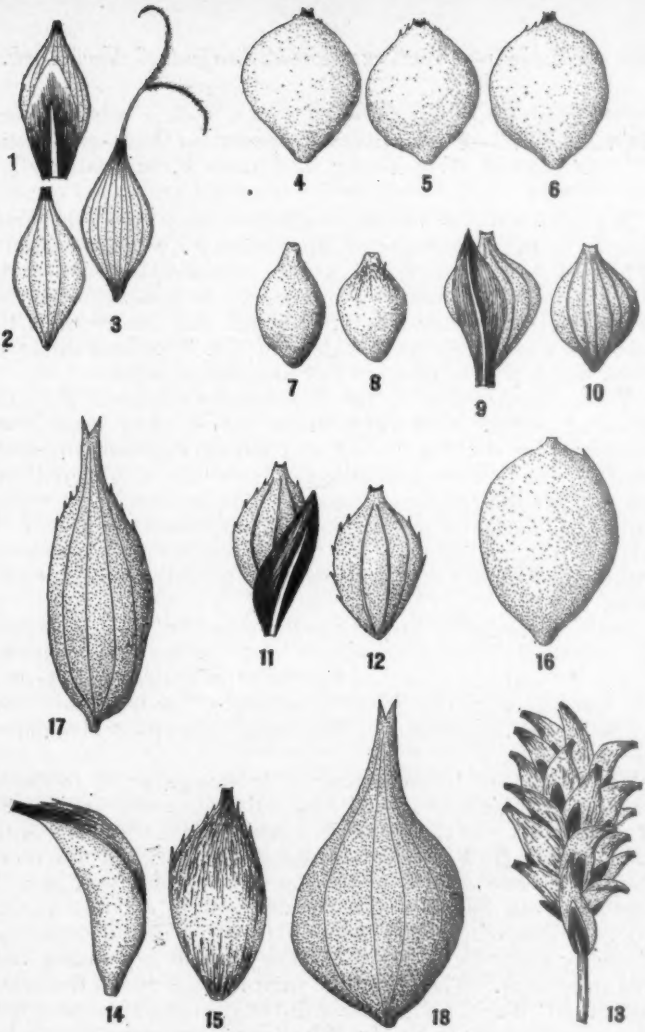


FIGURE 1. Perigynium and scale of *Carex linnæa*.
" 2. Perigynium of same, inner face.
" 3. Perigynium of same, outer face.
" 4–6. Perigynium of *Carex brachypoda*, outer face.
" 7, 8. Perigynium of *Carex pachystoma*, outer face.
" 9. Perigynium and scale of *Carex eurycarpa*.
" 10. Perigynium of same, outer face.
" 11. Perigynium and scale of *Carex oxycarpa*.
" 12. Perigynium of same, outer face.
" 13. Pistillate spike of *Carex campylocarpa*.
" 14. Perigynium of same, side view.
" 15. Same, outer face.
" 16. Perigynium of *Carex cryptochlæna*, outer face.
" 17. Perigynium of *Carex luzulæfolia*, outer face.
" 18. Perigynium of *C. luzulæfolia* var. *strobilantha*, inner face.

All figures magnified.

Art. XXXIV.—*Preliminary Note on some Overthrust Faults in Central New York;* by Philip F. Schneider.

My attention was recently called to two unrecorded overthrusts in the limestones of this vicinity by Mr. Charles E. Wheelock, who discovered the same, and at whose request this preliminary notice has been prepared. In company with Mr. Wheelock the writer recently visited the locality and this description is largely confirmatory of Mr. Wheelock's observations, which will be given in full in a future paper.

These disturbances in the horizontally stratified Paleozoic rocks of central New York, where for so many years it was thought they could not exist and where the first announcements of such occurrences were received with such incredulity, are not yet sufficiently common to permit them to pass unrecorded. The faults are furthermore important because of the relation between them and the well known peridotite intrusives and the probability of the identity of the causes producing the same.

Both of the faults brought to light by Mr. Wheelock occur in some thinly bedded limestones which he correlates with the Bertie dolomite as described by Clarke in his recent report on the formations in the Tully Quadrangle,* or with the lower layers of the Waterlime of Vanuxem,† Geddes,‡ Schneider,§ and Luther.‖

The faults can be easily studied in the gorge of Butternut Creek, near Dunlop's station, one and one-quarter miles north of Jamesville. In the east cliff, a few yards to the south of the stairs leading from Fiddler's Green to the gorge of the creek, the thrust plane of the southernmost of the faults (Fault IV. Dunlop's) can be easily distinguished as it extends upward from the base of the cliff through its entire height, a distance of nearly thirty feet. At this point the cliff is comparatively free from talus. The dip of the fault plane is 28° to the northeast, N. 40° W. This northerly dip of the thrust planes of both of the faults located by Mr. Wheelock is interesting inasmuch as they seem to belong to a series of faults extending in an east and west direction across the country, which hade to the southward.¶ It is furthermore surprising as they occur about mid-

* Bulletin 82, N. Y. State Museum, 1905, J. M. Clarke.
† Rept. 3d Dist. N. Y. 1842.
‡ Geol. Survey of Onon., Rept. N. Y. State Agricultural Society, 1859.
§ Notes on Geol. of Onondaga Co., N. Y. 1893.
‖ Econ. Geol. of Onon., 15th Ann. Rept. N. Y. State Geol. 1895.
¶ This refers to the overthrusts in the Helderberg limestone series only and not to the slips and slides which are so common in or near the gypsum beds, and which can be explained by the expansion due to the formation of the gypsum, or to the solution of the gypsum or salt immediately underneath.

way between Gifford's and Russell's faults, the two disturbances showing the greatest amount of displacement and practically in a straight line with them. The layers have been sharply bent along both sides of the thrust plane and secondary crystals of calcite have been formed in the numerous fractures in and between the layers, but not as abundantly as at East Onondaga and Marcellus. Mr. Wheelock believes the amount of displacement is about four feet, but it is impossible to determine the thrust accurately because of the marked similarity of the layers of limestone.

The continuation of this fault may be seen in the west wall of the gorge, where it is not as easily accessible nor as readily studied because of the accumulated material. The bending and buckling of the layers is even more pronounced here than on the east side of the stream, although the displacement was apparently less.

Following the direction of the fault to the eastward, a cut on the trolley line just north of Dunlop's station is reached, showing some disturbance and a marked anticlinal fold. The fractured and disturbed condition of the layers in the entire cut and especially at the fold, which is directly in the line of the strike of the fault, makes it difficult to determine whether the faulting has reached upward to this point. The fracturing and shattering of the layers resembles somewhat that produced in certain of the layers overlying the gypsum, and lends color to the belief that Fiddler's Green marks the position of the gypsum deposit. A study of the gypsum ledge to the northeastward indicates that the gypsum occurs either just above or just below the cut showing the shattered layers, while a comparison of the altitudes of the adjoining gypsum deposits shows that it should occur at the Fiddler Green locality. Nevertheless it has not yet been noted there. However, the gorge of the creek lies below Fiddler's Green, hence it is hardly possible that the faults just described can occur in the Bertie limestone which is described by Clarke as overlying the gypsum. However, according to Clarke's map the Bertie occurs in the gorge of the creek at this point.

Fault III. Dunlop's.—Following the gorge to the northward for a hundred yards or more, the folding and buckling of the layers give evidence of another disturbance. At this point the force seems to have exerted itself mainly in the bending of the layers, and without any large amount of displacement. The thrust plane of the fault is plainly visible, dipping at an angle of 23° to the northward. The displacement is not more than two feet. Fault III occurs in the same formation as that already described, the Bertie dolomite (?) The fault cannot be seen on the west side of the gorge because of a change in the

course of the stream here, which change in the direction is no doubt due in part at least to the existence of the fault right here.

Fault I. Dunlop's.—In making a cutting for Jamesville branch of the Suburban railroad about two years ago, two somewhat similar faults were exposed in the calcareous layers occurring three-eighths of a mile farther north. These layers may be continuously traced to the northeastward until they are found underlying the gypsum. They undoubtedly correspond with the limestone ledge mentioned by Clarke as containing the *Leperditia Scalaris* Jones, which occurs in the Camillus shale near the base of the Heard gypsum quarries. Inasmuch as there is only a difference of five feet in elevation between the altitude of these layers at faults I and II and faults III and IV with practically horizontal layers between the localities, it leaves little question but that faults III and IV occur in this same Leperditia Scalaris limestone and not in the Bertie. Fault No. I may be seen in the first cut showing the limestone, which is about 150 yards south of the crossing of the trolley and the Jamesville and Orville turnpike. The thrust plane of the fault cuts these somewhat thinly laminated layers, and dips at an angle of 35° to the south. The layers show little disturbance except at the fault line. Secondary calcite crystals occur in the fractures of the limestone, near the fault.

Fault II. Dunlop's.—Occurs in the same formation and in practically the same layers twenty yards south of fault No. I. The thrust plane dips south 32° and the layers are bent for several yards to the southward. The slickensided surfaces are well shown, also a slight tendency toward slaty fracture. Calcite crystals are lacking. The displacement is slight, probably not more than three feet. The fault maintains its character throughout the entire height of the cut. Owing to an accumulation of talus and the dense vegetable growth the faults have not been located on the west side of the stream.

Other evidences of slight faulting are noticeable farther north in this cut, also some shearing of the layers with the formation of calcite crystals.

The overthrusts now known and described in central New York are—

(*a*) Russell's Quarry at East Onondaga, fault plane cuts the Manlius, Lower Helderberg, Oriskany, and Onondaga formations. Displacement forty-two feet. Also shown in Hibbard's and adjoining quarries. Rocks affected for over a mile to the eastward as shown by the marked slaty cleavage in the finer grained limestones of the Corniferous.

Luther, "Econ. Geol. of Onon.," 15th Ann. Rept. N. Y.

State Geologist, 1895. Schneider "Science Series, No. 2.," Onon. Acad. Science publication, 1899.

(*b*) Maylie's Quarry at Marcellus, cuts Corniferous and Seneca layers of the Onondaga. Displacement, three feet. Shown in adjoining quarries for over one-half mile to westward. Thrust plane dips 17° to N. See preceding references.

(*c*) Gifford's Glen, two miles west of Manlius. Cuts the Onondaga and Marcellus groups. Decidedly interesting because of the remarkable manner in which the heavy layers of Onondaga limestone have been arched and bent. Thrust plane not visible. Luther makes the elevation of the limestone sixty feet, but says it is due to bending.

(*d*) Fillmore's Corners, one-half mile west of preceding. Cuts Onondaga and Marcellus groups. Displacement, fifteen feet. "Geological Fault at Jamesville," Schneider. This Journal, vol. iii, 1897.

(*e*) Indian Reservation Quarries. Two faults cut Onondaga formation. Dip 23° S. Total displacement of the several faults about six feet. Schneider, "Science Series No. IV," Onon. Acad. Sci. 1905.

(*f*) Dunlop, No. I, cuts Scalaris limestone in Camillus shale. Displacement, three feet. Dip, 35° S.

(*g*) Dunlop, No II, Scalaris limestone. Displacement, three feet. Dip, 32° S.

(*h*) Dunlop, No. III, cuts Bertie dolomite (?) Displacement, two feet. Dip, 23° N.

(*i*) Dunlop, No. IV, Bertie dolomite (?) Displacement, four feet. Dip, 28° N. E.

(*j*) Heard's gypsum quarry. A small overthrust in the Camillus shale occurs here, apparently more deeply seated than the displacements so common in the gypsum quarries due to the formation and subsequent solution of the gypsum.

The writer also has MS. notes and drawings of several small faults occurring in the Camillus shale near the peridotite dikes which were temporarily exposed during the trenching of that region for city water.

At the Solvay quarries at Split Rock in the Manlius and Onondaga formations and in some of the adjoining abandoned quarries several sharp folds and some slickensided surfaces occur which tell of further disturbances. Similar evidences occur in Madison Co. in the vicinity of Chittenango Falls to the east of the described localities, while to the westward they may be seen in the same ledge about Auburn in Cayuga Co. Cleland* mentions a fault in the outlet of Keuka Lake, still far-

* "A Study of the Fauna of Hamilton formation of the Cayuga Lake section in central New York," H. F. Cleland, Bulletin No. 206, U. S. Geol. Survey.

ther west, but no facts are given, while the folds in the higher formations are well shown in long arch at Cayuga Lake, and similar undulations in strata at Seneca. Disturbances are also noted by Lincoln in his account of the geology of Seneca Co.*

Inasmuch as most of the above mentioned disturbances occur in or near the Helderberg escarpment, composed in the main of heavy limestones aggregating several hundred feet in thickness, and the persistence of the faults across central New York, it would seem that all are the result of some considerable force capable of affecting this entire region. In a general way the solution of the salt from the Salina formation which immediately underlies the Helderberg series has been regarded as an explanation for all the disturbances in this vicinity. Mr. Wheelock believes that the solution of all of the saline ingredients of the Salina rocks together with the slight dip of rocks of central New York is a sufficient explanation for the faulting, as any settling of the layers must shorten the length of the hypothenuse of the triangle and thus produce the force which crumpled and fractured the rocks. The fact that the softer shales sandwiched between the limestone bands are sometimes bent and sheared while the harder layers are not affected, and that the larger throws all occur in the more resistant layers, he believes will favor his explanation. This, however, would be true irrespective of the cause, provided of course that it were compression. It has also been suggested† that expansion due to the formation of gypsum would explain the faulting. While considering the causes of the faults it would be well to keep in mind that there is a series of widely known intrusives which parallel north and south this series of faults, and which extend across the state from Little Falls on the east to Ithaca on the west, and it is not impossible that both faults and dikes owe their origin to the same general disturbance. The consideration of this question, however, will be left to another paper.

Syracuse, N. Y.

* "Geol. of Seneca Co.," Rept. N. Y. State Geologist, 1894.
† E. H. Kraus, verbally.

ART. XXXV.—*Petrography of the Tucson Mountains, Pima Co., Arizona;* by F. N. GUILD, University of Arizona. (With Plate IX.)

THE Tucson Range of mountains is located directly west of Tucson and is about twenty miles long with an average width of about seven miles. It consists of a series of jagged peaks extending nearly north and south, the higher ones of which are estimated to have an altitude of 4000 feet above sea level. The approach to the main line of peaks is over a series of low-lying rounded knolls devoid of all vegetation except a few cacti and other stunted growths characteristic of an arid region.

Petrographically quite a variety of rocks are represented which are almost entirely eruptive. There occur, however, in places, remnants of the original quartzites and limestones through which this great mass of lava has broken. On the west side of the range and southwest of Tucson is an elevated plateau of an area of one hundred square miles or more, consisting entirely of these limestones and quartzites. It is quite level and the beds are exposed only along its edges and near the center where the uplifted strata form two small buttes, consisting almost entirely of crystalline limestone tilted to an angle of about forty-five degrees.

It is the purpose of this paper to describe from a petrographical standpoint the eruptive rocks without discussing their geological relations. The question of names and classification is not taken up, the writer considering descriptions of more importance. With this introduction, they will be described in the order of their relative abundance.

Rhyolite.—The main line of jagged peaks referred to above is made up of this rock, varying in color from a dark red to nearly white. Phenocrysts are inconspicuous, not very abundant and rarely exceed three millimeters in diameter. They consist of quartz and less abundant orthoclase. Under the microscope, the quartz is found to occur in rounded masses corroded by the groundmass with frequent inclusions of the latter in the form of bag-shaped inlets. Black dust-like inclusions and glass with gas bubbles are common. The feldspar, although much decomposed and containing opaque inclusions, still shows the characteristic cleavage of orthoclase. The groundmass in the darker varieties is too much altered to show any characteristic texture. In the southern portion of the district, however, material is sometimes met with of sufficient freshness to admit of satisfactory study, and here it is found to have a cryptocrystalline structure. Specimens of it are frequently found possessing faint flow lines, sometimes vis-

ible to the unaided eye, but usually requiring a microscope to be seen. (Fig. 1, Plate IX.) Occasionally dark shredded masses occur which may have been originally mica. All varieties contain irregular inclusions of varying size, sometimes two inches across, of a red jasper-like substance or of sandstone or quartzite. Frequently also rounded patches are met with which under the microscope are found to be made up of quartz and feldspar in equidimensional crystals, which may represent areas of more complete crystallization of the groundmass.

Associated with these more typical rhyolites are large masses usually of a light yellow to buff color, lacking all phenocrysts. They correspond to rocks which have been variously called felsite, felsophyre, granophyre, etc. They sometimes break with conchoidal fracture, but are more often too coarse-grained to show this characteristic. Under the microscope, quartz, feldspar and sometimes shreds of mica can be seen in the coarser varieties. The finer-grained types are made up entirely of cryptocrystalline material in which none of the constituents can be determined.

Rhyolitic Tuff.—Associated with the outflow forming the main rhyolite peaks, there were probably formed masses of volcanic ash. The greater portions of this have been washed away, but occasionally where geological conditions have been favorable some of this material has become consolidated into a compact rock of light gray color of sufficient strength to be used extensively in building. Underlying Sentinel Peak in places there are small masses of it which have been held in place by the basaltic outflow. Under the microscope it is found to be made up of fragments of quartz, feldspar, glass, etc. It is interesting to note that the quartz has the same kind of inclusions as the quartz phenocrysts in the rhyolite described above.

Andesites.—Several types of this rock varying greatly in appearance and texture occur. They may be grouped rather roughly as follows:

1. Light-colored andesites containing phenocrysts of mica or hornblende or both and of feldspar. 2. Dark-colored andesites of non-porphyritic texture. 3. Vitrophyric andesites.

The first variety covers an area only slightly less in extent than the rhyolites and constitutes the material of the low-lying knolls previously referred to. It has usually a mottled appearance not unlike that of some granites. The feldspar is pure white and the groundmass varies from white to greenish gray. The chief variation is in the black ferro-magnesian minerals, which are most often biotite, but in some localities hornblende predominates, while in still others the black phenocrysts are quite inconspicuous. Under the microscope the feldspar is clear,

usually striated, and as shown by the extinction angles on the twinning plane appears to be an acid plagioclase. The biotite is quite fresh and of the usual dark yellow-brown color. Hornblende has become darkened by alteration and is often quite opaque. The groundmass is crystalline and made up mostly of feldspar with some magnetite and shreds of the dark silicates.

The second variety is found in the northern portion of the district near the edge of the mountains about twelve miles from Tucson. It varies greatly in both megascopic and microscopic structure in different parts of the same mass. Its general appearance is more like that of a diabase except in portions where phenocrysts of feldspar appear. It is very dark with a slight green tinge weathering red. Porphyritic texture is not conspicuous and may be megascopically absent. Under the microscope, however, the rock is found to consist of crystals of plagioclase, pyroxene, and biotite in a variable groundmass. In some portions the distinction between groundmass and phenocrysts is very marked, the groundmass being typically andesitic, while in other parts there is comparatively little difference in size between the constituents of the groundmass and the phenocrysts. The pyroxene is light yellow-green in color with high extinction angle and non-pleochroic and rarely occurs in crystals longer than one millimeter. The plagioclase phenocrysts are usually somewhat larger, ordinarily clear but sometimes opaque from decomposition. The biotite appears in rather small crystals compared with the other phenocrysts and is of a light yellow-brown color with darker borders. In altered specimens the dark-colored constituents have decomposed into yellow non-pleochroic masses.

The third variety, or vitrophyric andesite, is also found in the northern portion of the district as a low rounded ridge not more than one hundred feet above the surrounding country. It is also a pyroxene mica andesite, and is distinctly porphyritic, the phenocrysts occupying fully one half of the entire mass of the rock. Black mica and feldspar are very conspicuous and occasionally orthoclase crystals eight millimeters in length showing well-formed Carlsbad twins occur. The groundmass varies from a nearly black to light gray transparent glass. Under the microscope the feldspar is found to be of plagioclase and of an unstriated variety. It frequently possesses zonal structure and is often much broken, appearing in angular fragments. The biotite is in fresh hexagonal plates and irregular shreds. Pyroxene is light green and shows high extinction angle. Magnetite is present in the usual quantities. The groundmass is isotropic and filled with what appear to be small fragments of the phenocrysts and very small crystallites.

Fine flow-lines and perlitic cracks occur in places. This variety of andesite is very common in southern Arizona and frequently possesses flow-lines of remarkable beauty. (Fig. 2.) In the upper part of the andesite the groundmass has become entirely opaque through devitrification.

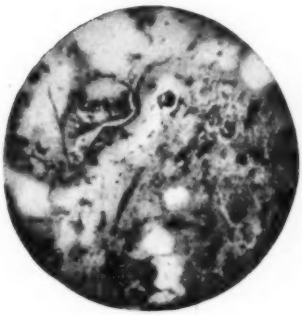
Basalt.—Outflows of this rock occur at various intervals along the edges of the mountain range especially west and south of Tucson. They vary greatly in character and may be grouped into the following varieties:

1. Fine-grained olivine basalt.
2. Porphyritic basalt.
   - *a.* Containing phenocrysts of feldspar and augite, in a coarse-grained or doleritic groundmass.
   - *b.* Containing porphyritic crystals of feldspar only in a basaltic groundmass.
   - *c.* Containing feldspar, augite and olivine in an andesitic groundmass.
3. Quartz basalt.

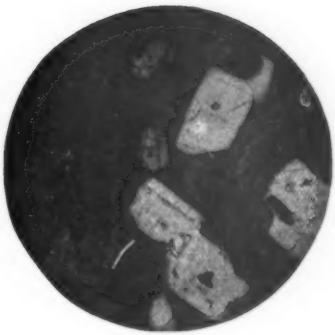
One of the most prominent of these basaltic outflows is one mile west of Tucson in the form of a symmetrical cone-shaped mass called Sentinel Peak. Immediately northwest of this is another irregular dome-shaped mass of the same rock. It is further represented in two promontory-shaped outflows southwest of the San Xavier Mission and ten miles south of Tucson. These elevations are made up chiefly of the fine-grained type of basalt in which none of the constituents can be recognized with the naked eye. It is usually compact and free from cavities, but occasionally is found quite cellular and even scoriaceous in structure. The cavities are sometimes rounded in outline with a diameter of one half inch or more, but are more often drawn out by movements of the mass when in a molten condition into irregular channels. These cavities are usually empty, but are sometimes filled with gypsum or aragonite. The predominating color is black, but deep red varieties are met with, especially in the San Xavier outflow. In places pressure and movement of the mass have developed a schistose structure, the laminations frequently being nearly vertical. This is especially noticeable on the dome-shaped mountain mentioned above near the Carnegie Desert Botanical Laboratory, and leads to the conjecture that the vent through which the basalt escaped is located under it.

Microscopically the rock is made up of numerous feldspar rods crowded together and frequently arranged in flow-lines, large amounts of magnetite and rather small quantities of olivine. Glass is present in greatly varying quantities. The olivine occurs mostly in rounded grains with a dark red halo

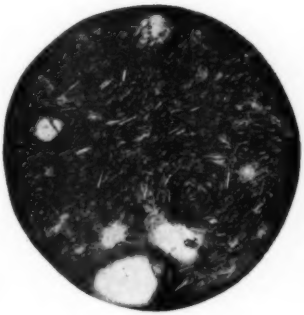
1



2

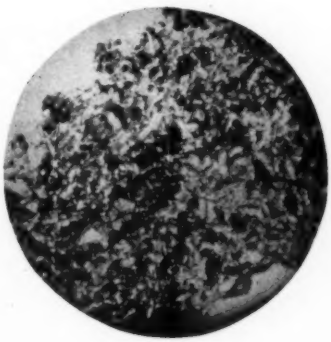


3



4

5



6

of ferritic material and occasionally the interior of the crystal has been reabsorbed leaving skeletons filled by the groundmass. (Fig. 3.) The accompanying illustrations (figs. 3, 4) will show the most important variation in this type of basalt. In fig. 4 the constituents are more porphyritically dispersed than is usual in these outflows and the groundmass contains more isotropic material, yet to the unaided eye they all appear nearly identical.

Porphyritic basalt of the first type (*a*) is found underlying the compact basalt of Sentinel Peak at its southern extremity. That this represents an outflow distinct from the compact variety is shown by the sharp contact between the two, where there is a layer of dark red basaltic tuff and breccia from two to six feet thick. A rock practically identical with this is found at the San Xavier Mission in a small cone-shaped elevation. This variety appears to be made up of large plagioclase crystals constituting nearly one half of the mass, and frequent black lustrous crystals of augite in a groundmass varying from coarse crystalline to compact. The feldspar crystals are sometimes over one half inch in length and frequently broken. Under the microscope they are found to be quite fresh, twinned plagioclase filled with dark inclusions of the groundmass. The pyroxene is light yellow with parallel cleavage cracks and high extinction angle. The groundmass, where it can be made out with the microscope, is mostly feldspar and augite with but small amounts of glass. Olivine is not at all abundant and in some slides is absent. (Fig. 5.)

The second type of porphyritic basalt (*b*) is found as occasional outflows south of Sentinel Peak, the largest yet observed being about seven miles from Tucson. The color of the rock is medium dark gray, and the only minerals which can be determined in it by the naked eye are feldspar and occasionally magnetite. The feldspar is rarely over one quarter inch in length and is more rod-shaped than in the foregoing type. It becomes very conspicuous only as the rock weathers. Under the microscope the feldspar is like that in the first type. The groundmass can hardly be resolved by the microscope but seems to consist mostly of feldspathic material and magnetite.

The third type of porphyritic basalt (*c*) occurs in a very small mass not more than one hundred feet in length at the southern base of Sentinel Peak. Portions of the mass are amygdaloidal and much decomposed. The amygdules are sometimes six inches in diameter and filled with agate, usually in concentric rings of varying translucency, or with calcite or siderite. Sometimes there is an outer shell of agate, the interior being filled with calcite. Geodes of brilliant smoky quartz have also been found. In places the rock is sufficiently

fresh for satisfactory study. To the naked eye the porphyritic character of the rock is not at all apparent. Under the microscope, however, it is found to be made up of distinct porphyritic crystals of abundant feldspar, considerable pyroxene, and much less olivine in a semicrystalline groundmass consisting of a felt of magnetite and dark matter which reacts feebly under polarized light.

Quartz basalt.—This unusual type of basalt is found in the extreme southern end of the mountain range as a portion of the promontory-shaped hill two miles southwest of the San Xavier Mission. The greater portion of the outflow consists of the compact basalt already described with cellular and scoriaceous modifications. On the extreme eastern slope an abundance of the quartz-bearing variety appears. Quartz is the only mineral that can be detected with the naked eye. Aside from this porphyritic constituent the general character of the rock from both a megascopic and microscopic standpoint is the same as the compact varieties described above. The quartz occurs as rounded and semi-angular grains, rarely more than six millimeters in length. Under the microscope the quartz appears clear, much fractured and quite free from inclusions of all sorts. That the quartz is primary and not due to secondary filling of cavities is inferred from the fact that the grains each consist of but one individual as shown by the extinction. This is not the case where previously existing cavities have been filled by infiltration. Amygdaloidal fillings have been observed in this same rock and they present a structure quite different from the quartz in question. Basalts containing quartz have been described by Diller,* Iddings† and Pirsson‡ from various localities in the United States, and by Andreae§ and Lacroix‖ from other regions. By most of these writers their origin has been discussed and they have been held to be of primary origin. Some, like Lacroix, have, however held them to be inclusions, quartz grains caught up from lower rocks and held in the magma.

DESCRIPTION OF FIGURES, PLATE IX.

FIGURE 1.—Rhyolite, showing flow-lines in the groundmass, ordinary light, 18 diameters.

FIGURE 2.—Vitrophyric andesite, near Gila Bend.

FIGURE 3.—Basalt, Sentinel Peak, 45 diameters.

FIGURE 4.—Basalt, near San Xavier, 45 diameters.

FIGURE 5.—Porphyritic basalt, showing crystals of augite, 18 diameters.

FIGURE 6.—Agate, under polarized light, showing complicated structure, found as amygdaloidal filling in porphyritic basalt (*c*), 45 diameters.

* This Journal, vol. xxxiii, p. 45, 1887. Bull. U. S. Geol. Surv. 79, 1891.
† This Journal, vol. xxxvi, p. 208, 1888. Bull. U. S. Geol. Surv. 66, 1890.
‡ Bull. U. S. Geol. Surv. 139, p. 129, 1896.
§ Zeit. deut. Geol. Gesell, 1892, p. 824.
‖ Enclaves des rockes volcaniques, Ann. Acad. Macon, vol. x, 1893, p. 17.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Gases produced by Actinium.*—It is known that solutions of radium salts give off continuously a mixture of hydrogen and oxygen from the decomposition of water, and it has been found that this detonating gas contains a small quantity of helium which is believed to be a product of the disintegration of the radium atom. Debierne has recently confirmed this behavior of radium by using nearly a tenth of a gram of Curie's radium bromide and operating in a manner similar to that of Ramsay and Soddy. He has found, further, that solutions of actinium salts give off detonating gas containing helium, and that the amounts of these products apparently correspond to the amounts produced by a quantity of radium having the same activity.

For the experiments with actinium he used the whole of his most active products, and obtained the same results with a portion which had been specially purified from any possible contamination with radium by adding to it barium chloride and removing the barium. It was found, moreover, that the barium thus removed did not contain an appreciable quantity of radium. It was found also that solid actinium fluoride gave off helium. Debierne states that in addition to the large quantity of emanation with a rapid rate of decay which is given off by solid salts of actinium, there comes from it a very small quantity of an emanation of much slower change which he has identified as identical with the radium emanation; but its quantity is too small to have produced the helium found in his experiments.—*Comptes Rendus*, cxli, 383. H. L. W.

2. *A New Heavy Solution.* — Duboin has prepared some liquids analogous to the well-known Thoulet's solution, one of which, at least, appears to possess decided advantages over the latter. In the place of the potassium iodide used by Thoulet, he uses sodium or lithium iodide. The alkaline iodide and mercuric iodide are alternately added to a small quantity of water until saturation takes place, the temperature being slightly raised at the end of the operation. Then the liquid is allowed to cool, and after twenty-four hours it is filtered. It was found that Thoulet's solution prepared in this way, and filtered at 22·9°, gave a specific gravity of 3·196 and an index of refraction of 1·730, while the sodium mercuric iodide solution, filtered at 24·75°, gave a density of 3·46 and an index of refraction of 1·797. The lithium solution is intermediate in its density and refraction between the two just mentioned. Analyses of the solutions showed that their compositions corresponded closely to the formulas K_2HgI_4, Na_2HgI_4 and Li_2HgI_4, and in each case the amount of water present was somewhat more than 10 per cent. A similar ammonium mercuric iodide solution was prepared, but this was less dense than Thoulet's liquid.

The sodium mercuric iodide solution is of considerable interest, as it is heavier than even methylene iodide. Although water produces in it a precipitate of mercuric iodide, it dissolves without change in alcohol and many other organic liquids.—*Comptes Rendus*, cxli, 385. H. L. W.

3. *Hydrolysis of very Concentrated Ferric Sulphate Solutions.*—It has been observed by RECOURA that a concentrated solution of ferric sulphate made by dissolving the anhydrous salt in its own weight of water is completely decomposed when it is placed in contact with acetone for several days. The products are sulphuric acid, which dissolves in the acetone, and a basic ferric sulphate which separates in the solid form. The latter is yellowish white in color, is soluble in water, and has a composition represented by the formula $6Fe_2(SO_4)_3 . Fe_2O_3 . H_2O$. The same solid is formed without the use of acetone when a strong solution of ferric sulphate is placed in a well-stoppered flask and allowed to stand for a longer time. With solutions of the strength given above, the deposit begins to form after about twelve days and extends through the liquid in about a month. With stronger solutions the precipitate is formed more rapidly and abundantly, while with solutions slightly more dilute no basic salt separates. The deposit is formed most rapidly at 20°, and more slowly as the temperature is kept lower.—*Comptes Rendus*, cxl, 1685. H. L. W.

4. *Separation of Gold from the Metals of the Platinum Group.*—JANNASCH and VON MOYER have found that gold is precipitated quantitatively by a salt of hydrozine in any kind of solution. This reagent, however, on account of its powerful reducing action does not serve to separate gold from the metals of the platinum group, although it is thus separated satisfactorily from potassium, sodium, barium, strontium, calcium, magnesium, aluminium, chromium, zinc, manganese, iron, uranium, nickel, cobalt, cadmium, mercury, lead and copper. Gold is precipitated by a hydroxylamine salt in acid solution somewhat slowly, and not below a temperature of 80°. Preliminary tests indicate that hydroxylamine hydrochloride is a satisfactory reagent for the separation of gold from palladium, platinum, iridium and rhodium, as well as from ruthenium and osmium.—*Berichte*, xxxviii, 2129. H. L. W.

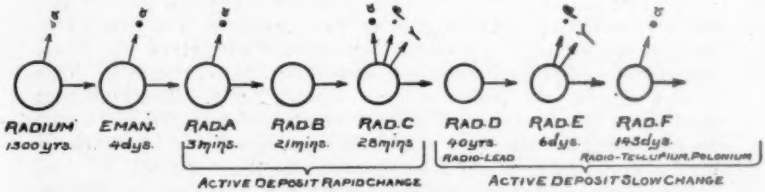
5. *Determination of Sugar with Fehling's Solution.*—On account of difficulties encountered in determining small quantities of sugar by Fehling's volumetric method, LAVALLE has modified this by carrying it out in the presence of an excess of caustic soda, so that the cuprous oxide produced remains in solution, and the change in color is more readily detected. The operation is as follows: In a porcelain dish of 200^{cc} capacity are placed 5 or 10^{cc} of Fehling's solution, 30^{cc} of sodium hydroxide solution (1 : 3), and 50 or 60^{cc} of distilled water. The liquid is then heated, and when it begins to boil the solution to be tested is gradually added. The operation is finished when the last drop causes the blue color of the Fehling's solution to disappear.—*Berichte*, xxxviii, 2170. H. L. W.

6. *Slow Transformation Products of Radium.*—An article by Prof. E. RUTHERFORD, in the September number of the Philosophical Magazine, closes with the following summary of the products recognized in the slow transformation of radium.

"The results of the comparison of the products of radium with those contained in polonium, radio-tellurium, and radio-lead are summarized below.

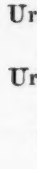
Products in old Radio-lead.	Radium D = product in *new radio-lead*, no rays. Half transformed in 40 years.
	Radium E = gives out β rays, separated with bismuth, and iridium. Half transformed in 6 days.
	Radium F = product in polonium and radio-tellurium. Gives out only α rays. Half transformed in 143 days.

The family of substances produced by the disintegration of radium, together with the time for each to be half transformed, is shown diagrammatically in the figure.



It is now fully established by the researches of Boltwood, Strutt, and McCoy that the amount of radium present in radioactive minerals always bears a constant ratio to the amount of uranium. The investigations of Boltwood, in particular, have shown a surprisingly good agreement between the content of radium and uranium for minerals obtained from various localities, which differ very widely in their content of uranium. This proportionality is a strong indication that radium is produced from uranium; and a conclusive proof of this point of view is given by the experiments of Soddy and Whetham, who find that there is a slow growth of radium in uranium which was initially freed from radium. In addition, the actual amount of radium in radioactive minerals is of the right order of magnitude to be expected from theoretical considerations, if uranium is the parent of radium.

Soddy finds that the present growth of radium from uranium is only a very small fraction of the theoretical amount. This is most simply explained by supposing that one or more products of slow period of transformation intervene between UrX and radium. The uranium-radium family and their connection with one another is summarized below.



Radium and its family of rapidly-changing products, viz., the emanation, radium A, B, and C.

Radium D = primary constituent in radio-lead.

Radium E.

Radium F = active constituent in radio-tellurium and polonium.

No evidence has been obtained that any further active products exist after radium F has been transformed. If the α particle is a helium atom, remembering that five products are present in radium which emit α particles, the atomic weight of the transformation product of radium F should be 225—20 or 205. This is very close to the atomic weight of lead, 206·7. The view that lead is the final or end product of the transformation of radium is supported by the fact that lead is always found in the radioactive minerals in about the amount to be theoretically expected from the content of uranium, when the quantity of helium, present in the mineral, is used to compute its probable age.* A similar suggestion has recently been advanced by Boltwood."

II. Geology and Mineralogy.

1. *Indiana, Department of Geology and Natural Resources, Twenty-ninth Annual Report*, W. S. Blatchley, State Geologist, 1904. 888 pp., 34 pl.—This Twenty-ninth Report of the State Geologist of Indiana is largely devoted to the economic interests of the state, which have shown a very large increase in recent years. Thus comparing the figures for 1895 with those for 1904, although there has been a falling off in natural gas, the amount of coal produced has been more than doubled and that of petroleum increased nearly three times, while the value of the output of building stone and of clay products has also doubled. Twenty-five years since the resources of the state were almost exclusively agricultural, while in 1904 the total value of the mineral resources amounted to not less than forty million dollars. The present volume discusses very fully the c[illegible]s and clay industry of the

* A full discussion of this question was given by the writer in the Silliman Lectures, Yale University, March, 1905.

state, in which direction the state has been found to be very rich, the shales, particularly those of the Coal Measures, which were not many years since supposed to be valueless, now being turned on an extensive scale into pipes and tiles, bricks of various kinds and other products. An account is also given of the petroleum industry, and the volume closes with an illustrated chapter upon the insect galls of Indiana by Melville T. Cook.

2. *Geological Survey of Louisiana, G. D. Harris, Geologist-in-charge.*—It is announced that hereafter the biennial reports of the State Survey of Louisiana will be brought out first as Bulletins and subsequently will be bound up in part as regular volumes. Of the Report of 1905, three Bulletins have already appeared: No. 1—The Underground Waters of Louisiana; No. 2—Magnetic Survey of Louisiana; and No. 3—Tide Gauge Work in Louisiana. These may now be had gratis by addressing Dr. W. R. Dodson, Director Experiment Station, Baton Rouge, La.

3. *Geological Survey of New Jersey. Annual Report of the State Geologist, Henry B. Kümmel, for the year 1904.* 317 pp., 19 plates, 18 text figures. Trenton, 1905.—This report contains a popular account of fossil fishes and their place in paleontology, by Dr. C. R. Eastman, followed by a detailed account of the fossil fishes of the Triassic as found in the Newark formation. Dr. Weller contributes papers on the faunas and corresponding formations of the Cretaceous of New Jersey. Professor F. B. Peck has a chapter on the talc deposits of Phillipsburg, N. J., and Easton, Pa., while the molding sands are treated by H. B. Kümmel and S. H. Hamilton. Progress is noted in the survey of the pre-Cambrian rocks in coöperation with the United States Geological Survey, and further parts treat of well records, forest fires and mining. The work throughout the report is thorough and of high grade; it deals largely with subjects of practical value to the state. J. B.

4. *Brief descriptions of some recently described Minerals.*—BECKELITE is a silicate of the cerium metals and calcium, described by J. Morozewicz and named after Prof. Fr. Becke of Vienna. It is found in a rock of the eleolite-syenite type, called by the author mariupolite and forming one of the petrographic elements of the Azov granite table. It occurs in coarse grains of a light yellow color, optically isotropic, also in octahedrons and dodecahedrons resembling pyrochlore. The hardness is 5 and the specific gravity about 4·15. An analyis yielded:

SiO_2	$ZrO_2+R_2O_3$	Mn_3O_4	CaO	MgO	K_2O	Na_2O	ign.
17·13	65·31	0·07	15·46	tr.	0·39	0·78	0·99=100·13

The rare elements forming the 65·31 of $ZrO_2+R_2O_3$ included the following: ZrO_2 2·50, Ce_2O_3 28·10, La_2O_3 13·60, Di_2O_3 18·00, $Y_2O_3+Er_2O_3$ 2·80, Al_2O_3 0·30, Fe_2O_3 tr. The calculated formula is $Ca_3(Ce, La, Di)_4Si_3O_{15}$.—*Min. petr. Mitth.*, xxiv, 120, 1905.

Several new species are described by R. H. Solly, in a recent number of the Mineralogical Magazine (xiv, 72). They are

derived from the dolomite of the quarries in the Binnenthal, Switzerland. HUTCHINSONITE, named after Dr. Arthur Hutchinson, of the University of Cambridge, is a species occurring in prismatic orthorhombic crystals, with numerous terminal faces. The color is gray to grayish black, and the streak vermilion. The crystals are transparent to nearly opaque. Hardness, 1·5–2; cleavage, good, parallel to the macropinacoid. In composition it is found by G. T. Prior to be a sulpharsenite of thallium, lead, silver and copper; it contains nearly 20 per cent of the rare element thallium.

SMITHITE, named after Mr. G. F. Herbert Smith of the British Museum, occurs in monoclinic crystals, resembling flattened hexagonal prisms, with prominent bas alplane. The lustre is adamantine, the color light red, and the streak vermilion. The crystals are transparent to translucent. Hardness, 1·5–2; cleavage, parallel to the orthopinacoid, perfect. The surface of the crystals changes on exposure to light from pure red to orange red. According to G. T. Prior, the composition is expressed by the formula $AgAsS_2$.

TRECHMANNITE, after Dr. C. O. Trechmann, occurs very sparingly in minute rhombohedral crystals resembling the two species hutchinsonite and smithite in color, streak and hardness. The crystals showed portions of hexagonal prisms, with small pyramidal and rhombohedral faces. Cleavage was observed perpendicular to the prism. The composition is as yet undetermined.

MARRITE, named after Dr. John Edward Marr of Cambridge, occurs in highly modified monoclinic crystals, usually doubly terminated. The color is lead- to steel-gray, the surface showing iridescent tarnish; the luster is metallic, brilliant. The hardness is 3 and the fracture conchoidal; no cleavage was observed. Only a single specimen had been found at the time the description was published; this showed some fifteen small crystals implanted upon the dolomite, hence though the crystallographic data are complete the composition is yet to be determined.

LENGENBACHITE, named after the Lengenbach, a tributary stream in the Binnenthal, occurs in bladed crystals often very thin and sometimes curled up like paper. They show a highly perfect cleavage and splendent luster; the crystals are apparently twinned and are inferred to belong to the triclinic system. The plates are flexible and somewhat malleable but not elastic. The color is steel-gray, often with iridescent tarnish, the luster metallic; the specific gravity is 5·80. In composition it is essentially a sulpharsenite of lead with small amounts of antimony, silver and copper, as determined by A. Hutchinson.

BOWMANITE, named after H. L. Bowman of the University of Oxford, occurs in rhombohedral crystals with basic cleavage and having the form of six-sided plates, often grouped in rosettes; the crystals show a pseudo-symmetry in the basal sections. The color is honey-yellow, the luster brilliant vitreous to resinous. The hardness is 4·5, the specific gravity 3·2. According to Bowman it is essentially a phosphate of lime and alumina with small amounts of iron, water and possibly magnesia.